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ENHANCING DATA SHARING AND COLLABORATIVE ASSET LIFECYCLE SOLUTIONS IN THE FOREST INDUSTRY

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ABSTRACT

Ishaan Bhuchar: Enhancing data sharing and collaborative asset lifecycle solutions in the forest industry
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The simultaneous digital and green transition, commonly referred to as the twin transition, offers a pathway for businesses to implement more sustainable processes while also creating new business opportunities and avenues for growth. One business looking for a way to improve their practices is the target organization of this thesis: a forest industry company seeking more effective digital practices for data sharing across its production processes with different stakeholders. With a vast number of production-related assets, the business requires better practices for sharing asset-related data.

Firstly, this thesis aimed to understand the challenges, capabilities and motivational factors of different industrial businesses in joining a collaborative data sharing ecosystem. This was explored through interviews, which included the target organization of this thesis along with other businesses in the production asset lifecycle ecosystem. The second part of the research, focused on finding a concrete solution for the target organization to share data with external stakeholders. This was done by analyzing an existing data transmission platform, SAP's Business Network Asset Collaboration.

The results indicate that businesses increasingly recognize the impact that digitalization can play in moving towards sustainability-related goals. The value of data and data sharing is acknowledged across the industry, with interviewed companies expressing a willingness to move towards collaborative data-sharing practices. Sharing data throughout the production process was identified as a key enabler for the enhanced management of production-related assets. Nevertheless, organizational and technical concerns related to data-sharing were also identified, posing barriers that must be overcome for businesses to join a data sharing ecosystem.

Furthermore, the research finds that SAP's Business Network Asset Collaboration solution provides a structured and standardized environment for collaborative data sharing. The solution presents numerous benefits in terms of production efficiency and sustainability, addressing the needs and expectations of capital-intensive businesses desire.

Keywords: Digitalization, Twin Transition, Asset Lifecycle Management, Data Sharing

TIIVISTELMÄ

Ishaan Bhuchar: Datan jakamisen ja yhteistyöhön perustuvien omaisuuden elinkaariratkaisujen edistäminen metsäteollisuudessa
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Samanaikainen digitaalinen ja vihreä siirtymä – niin kutsuttu kaksoissiirtymä – tarjoaa yrityksille väylän kohti kestävämpiä prosesseja, avaten samalla uusia liiketoimintamahdollisuuksia sekä kasvumahdollisuuksia. Tämän opinnäytetyön kohdeorganisaatio on metsäteollisuusalan yritys, joka etsii keinoja toimintatapojensa parantamiseksi. Yritys pyrkii löytämään selkeämpiä ja tehokkaampia digitaalisia käytäntöjä datan jakamiseen tuotantoprosesseihin liittyviin tuotanto-omaisuuksien dataan liittyen ulkoisten sidosryhmien kanssa.

Ensimmäiseksi tässä työssä selvitettiin, millaisia haasteita, valmiuksia ja motivaatiotekijöitä teollisuusyrityksillä on liittyen yhteistyöhön pyrkivän datan jakamisen ekosysteemin liittymisessä. Tätä varten toteutettiin haastatteluja sekä kohdeorganisaation että muiden tuotantoprosesseissa olevien yritysten kanssa. Tutkimuksen toisessa osassa keskityttiin konkreettisen digitaalisen ratkaisun löytämiseen kohdeorganisaatiolle datan jakamiseen ulkoisten sidosryhmien kanssa. Tämä toteutettiin analysoimalla SAP Business Network Asset Collaboration ratkaisua.

Tulokset osoittavat, että yritykset tunnistavat digitalisaation merkityksen kestävyyteen liittyvien tavoitteiden saavuttamisessa. Datan ja sen jakamisen arvo koetaan selkeänä, ja yritykset haluavatkin siirtyä kohti datan jakamiseen perustuvaa ekosysteemiä. Kun dataa jaetaan läpi tuotantoprosessien, tuotanto-omaisuuden hallinta tehostuu merkittävästi. On kuitenkin huomattava, että datan jakamiseen liittyy organisatorisia ja teknisiä haasteita, jotka on ratkaistava, jotta yritykset lähtisivät ekosysteemin mukaan.

Tutkimuksessa todettiin myös, että SAP Business Network Asset Collaboration -järjestelmä tarjoaa jäsennellyn ja standardoidun ympäristön datan jakamiseen yritysten välillä. Tämä ratkaisu tuo mukanaan lukuisia hyötyjä tuotannon tehokkuuden ja kestävyyden kannalta pääomaintensiivisille yrityksille.

Avainsanat: Digitalisaatio, kaksoissiirtymä, tuotanto-omaisuuden elinkaaren hallinta, datan jakaminen

USE OF AI IN THESIS

I have utilised AI tools in my thesis:

☐ No

☒ Yes

The AI tools utilised in my thesis and their purposes are described below:

Names and versions of AI tools: ChatGPT 4o

Purpose of using AI tools:

The AI tool was utilized to ensure grammatical accuracy and improve the overall clarity of the text. All recommendations provided by the tool were critically evaluated and thoughtfully adapted to maintain the integrity and originality of my own writing style.

In addition, the tool was used for brainstorming ideas and acquiring new view points related to thesis research.

Sections where AI tools were used:

For grammatical accuracy, the tool was utilized throughout the text.

For brainstorming, the tool was mainly utilized for literature section and setting the overall structure of the thesis.

I acknowledge that I am fully responsible for the entire content of my thesis, including the parts generated by AI, and accept accountability for any violations of ethical standards in publications.

PREFACE

Firstly, I would like to thank Tero Junkkari and Joonas Halttunen from Metsä Group for giving me the opportunity to write my thesis for the company regarding such an interesting subject. Their guidance has been invaluable in shaping the direction of this thesis.

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Helsinki, 30 April 2025

Ishaan Bhuchar

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	Artificial Intelligence
ALM	Asset Lifecycle Management
BNAC	Business Network Asset Collaboration
BTP	Business Technology Platform
DT	Digital Transition
ERP	Enterprise Resource Planning
EU	European Union
GHGH	Greenhouse gas
IoT	Internet of Things
KPI	Key performance indicator
OEM	Original Equipment Manufacturer
SME	Small and Medium-sized Enterprises

1. INTRODUCTION

This chapter introduces the background related to the research with the current big issues presented. Following that, the research goals are stated with clear definitions for the research questions. The final part looks at the structure of the thesis.

1.1 Background

Only by implementing clear and decisive methods to combat climate change can the worst climate impacts be averted. The impact of climate change can also be seen around Europe, with events like floods, droughts, and extreme temperatures becoming increasingly prevalent [1]. This is why in 2019, the European Union (EU) launched the European Green Deal, which is a collection of policy initiatives guiding the EU towards a path of green transition. The big goal of this Green Deal is for the EU to be climate neutral by 2050, meaning net-zero greenhouse gas (GHG) emissions by that year [2]. In addition, another major target of the deal is to lessen the net GHG emissions by at least 55 % by 2030 compared to 1990 levels. To reach these ambitious targets, the EU established a legally binding goals for 2030 and 2050 in the form of the European Climate Law. This law is aiming to ensure that all the EU policies contribute to the big goal, requiring every sector of the economy and society playing their part [3].

One of the major avenues for achieving these significant goals related to climate change and sustainability is by embracing the twin transition approach. The twin transition approach acknowledges the vast, largely untapped potential of technology and data in advancing sustainability goals [4]. Instead of viewing digitalization and sustainability as separate initiatives, this strategy integrates them to maximize both efficiency and productivity. By adopting a twin transition approach, organizations can make their technological systems, data assets, and infrastructure more environmentally sustainable, while simultaneously driving broader sustainability initiatives across their operations [4].

The fast-paced advancement of digital technologies has significantly transformed the economic and social framework of European Union member states [5]. This digital shift plays a pivotal role in shaping the global progression of both society and the economy.

Moreover, digitalization offers the EU a possibility to solve many of the challenges it is currently facing and move towards a sustainable economy [6].

The impact of digitalization can be seen across businesses, as it has become a fundamental component of modern business strategies [5]. Digitalization leverages the power of information technology to create more efficient processes and to tap into new opportunities for growth. It is a deep change that organizations across industries need to embrace in order to be competitive. Over the past few decades, the information technology sector has undergone a monumental transformation, driven by the astronomical pace of technological progress [5].

Digital transition is spearheaded by data, which holds immense potential for tackling societal, climate, and environment-related challenges and leading the way towards a sustainable society [7]. A paper by Pothineni [8] analyzed over 200 businesses and found that organizations that comprehensively leverage data and have an evident strategy for managing data show higher profitability, efficiency, and competitiveness compared to businesses that lack such capabilities.

Along with the goals of the twin transition, it is important to recognize the economic benefits that can be realized through digitalization and the data economy. The market potential of data is massive, with the value of the EU's data economy reaching 325 billion euros in 2019, representing 2.6% of the region's GPD [9]. By 2025, this value is estimated to exceed 550 billion euros, representing 4 % of EU's GDP.

1.2 Issue

In the European Union, the industrial sector is responsible for around 20 % of the overall GHG emissions [10], highlighting the need to find new ways for to reduce these emissions and make industrial processes more sustainable. Fundamentally, the industrial sector is capital-intensive and utilizes plethora of production assets in its processes. By optimizing the utilization of these assets, it is possible to not only improve the overall production processes of a business but also reduce the amount of emissions emitted, enabling the transition towards a greener feature.

Businesses in capital-intensive industries, such as the forest, process, and energy sectors have indicated a need to create robust and sustainable collaboration practices based on data sharing across the production lifecycle between different stakeholders. This need

arises from the fact the required the proficiency required for in this area is lacking at the Finnish level, and, more broadly, at the European level [11].

This is why, in 2024, a two-year research project called Colife was started by the Finnish research institute VTT and Lappeenranta-Lahti University of Technology (LUT) to understand aspects related to the data economy in collaborative asset lifecycle solutions in the forest industry [11]. The research project is based on close collaboration between businesses in the production lifecycle, with the project aiming to conduct case studies and use cases related to ongoing production processes. These use cases provide a practical testing environments where future service solutions can be tested under real-word conditions [12].

One of the major drivers for the research project has been a company called Metsä Group, a significant forest industry company in Finland that is aiming to improve the utilization of their production-related assets and the associated data. Additionally, the Colife use cases will be conducted at different production sites of Metsä.

This thesis has been conducted for Metsä Group with the aim of finding out how to enhance collaborative data sharing in the production asset lifecycle between different stakeholders in the ecosystem. Additionally, the aim is to find a concrete digital solution that would enable Metsä to share production asset related data with external partners.

Although this thesis has been conducted in the context of Metsä's involvement in the Colife project, it is an independent piece of work that emphasizes Metsä's perspective, rather than reflecting the broader scope of the research project.

1.3 Goals and research questions

The creation of a collaborative data-sharing ecosystem is quite difficult to conduct. There are many different aspects that need to be considered, like ensuring that different parties utilize data as intended and overcoming technological challenges that impede the ability of businesses to share data effectively [13].

This is why this thesis aims to understand the capabilities and motivation factors of the different companies involved in the Colife project, while also understanding what the companies want to achieve through collaborative data sharing in an industrial context. Many of the companies in the research project are Metsä's partners in the production environment, conducting different tasks throughout production processes of Metsä. One of the key aims is to understand how businesses value the sustainability aspects related

to production asset lifecycle management and what are their capabilities of utilizing digitalization for achieving sustainability related goals.

Based on this, the first research question is formulated:

1. What influences a company's decision to take part in a data-sharing ecosystem within the collaborative asset lifecycle business?

The second research question wants to focus on the impact of digital technologies on enhancing data sharing in the collaborative data sharing context. The aim is to find out the impact of digitalization and how it offers a pathway of improving the production processes in the forest industry.

Based on this, the second research question is set:

2. What are the technologies that can be used to enhance data sharing in collaborative asset lifecycle solutions?

Finally, it is important to identify an existing digital solution that could be utilized for gaining the benefits related to shared data. The aim is not come up with a new solution or technology, but rather to utilize existing tools or platforms already existing. Ideally, such a solution should make the whole process of data sharing between different stakeholders in the production environment seamless, enabling benefits from both environmental sustainability and production efficiency perspective.

Thus the third research question is:

3. How to concretize the benefits of shared asset data from sustainable development and production efficiency perspective?

1.4 Thesis structure

This this is divided into eight chapters. Following this introductory chapter, Chapter 2 goes through the relevant literature related to digital transition, data economy, and asset management. The focus is on understanding the impact of digitalization, particularly focusing on the role that data plays for businesses. By examining existing research, the literature chapter establishes a theoretical foundation for the study. Following the literature chapter, Chapter 3 expands on the target company of this thesis and outlines the current issues the company faces. Additionally, this chapter provides an overview of the Colife research project.

Chapter 4 describes the methodology of this thesis, explaining different research approaches and justifying the chosen methodology, research design, and data collection methods. Chapter 5 is the first research part of the thesis, which consists of qualitative interviews of different businesses in the production asset lifecycle. Chapter 6 continues the research by analyzing an existing solution for data exchange within the production lifecycle between different stakeholders.

Chapter 7 is the discussion chapter of this thesis, analyzing the research results in depth and connecting them to the existing literature. Finally, Chapter 8 presents the conclusions of the thesis. This part explicitly answers the research questions, discussing the broader implications of the findings, and acknowledging the limitations of the research.

2. LITERATURE REVIEW

The literature review provides a foundation for the actual research with a thorough analysis related to twin transition and its impact on businesses, especially focusing on the significance of data economy. In addition, key aspects related to collaborative asset management are described.

2.1 Key digital technologies

For digital transition to take place, it is imperative to take advantage of technologies that are driving technological revolution [14]. These technologies form a pathway for societies and businesses to move towards more efficient and sustainable processes [14]. Figure 1 presents some of the key digital technologies required for digital transition to take place.

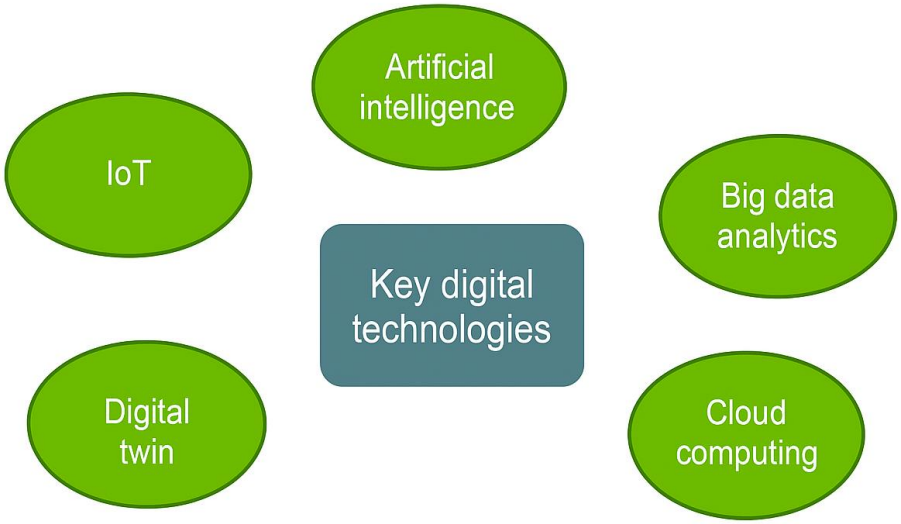

Figure 1. *Key digital technologies*

The internation Organization for Standardization defines Artificial Intelligence (AI) as “a technical and scientific field devoted to the engineered system that generates outputs such as content, forecasts, recommendations or decisions for a given set of human-defined objectives” [15]. AI’s effectiveness depends on the quality of the algorithms and machine learning techniques it uses, with it exceling at specific tasks but requiring vast amounts of data and repetition to achieve proficiency. At its core, AI analyzes large datasets, identifies patterns, and makes predictions or decisions, continually improving through learning.

A key subset of AI is machine learning, which enables machines to learn from data, identifying certain patterns and making decisions without the need for explicit programming [15]. Machine learning models are trained on massive datasets, which allow algorithms to automatically create connections within the data [16]. Machine learning enables computers to automatically learn and analyze complex data, and to make decisions and predictions about real-world events [17].

Another important subset of AI is natural language processing, which allows computers to understand, interpret, and generate human language [17]. This subset allows computers to analyze and examine text or speech data in a way that resemble humans. Applications of this technology include language translation software and chatbots. Natural language processing has transformed human-machine communication, making it more effective [17].

The advancement of artificial intelligence has generated significant economic value and positively influenced nearly every area of daily life, while also accelerating societal progress and marking the beginning of a new phase in social development [16]. The benefits of AI have led to great improvements in several industries, with aspects like automation, efficiency, and innovation increasing tremendously [18].

In the business context, the benefits of AI are tremendous and it can be seen from two broad categories [19]. The first category includes the automation benefits that AI provides. Through AI, it is possible automate tasks that are routine, handling different processing tasks of a business and business transactions that take place [20]. Many diverse set of tasks like human resources, banking, and logistics will be automated and conducted by machines, resulting in cost reductions while freeing up staff for more complex and strategic work [20]. The second major benefit of AI for businesses is the insights it delivers. By analyzing large volumes of data, it is possible to detect patterns

and improve businesses processes [20]. It enables the extraction of value from different types of data related to operations, customers, and different processes, creating economic value by analyzing patterns and trends that can be leveraged across different areas of the business. [19].

Another set of key technologies includes cloud computing and edge computing, which provide the infrastructure for processing and storing data. Cloud computing refers to computing services that are available on remote services over the internet, instead of having them on local servers or computer hard drives [21]. Cloud computing is a service provided through the internet, which makes it seamless for end-users to access computing resources. Other benefits of cloud include things like scalability and cost efficiency [21]. In contrast, edge computing processes data at the edge of the network, closer to the source of the data, rather than in centralized system like the cloud. This approach reduces the need to transfer data over long distances for processing, minimizing communication delays [22].

Internet of Things (IoT) refers to the network of physical objects that are connected with sensors, software, and other technologies. These devices are connected to one another through the internet, which allows for a progressively precise digital representation of the real world [22].

IoT relies on many other technologies. For example, through cloud computing, it is possible to store the extensive amount of data created from IoT devices. Moreover, through AI and machine learning, it is possible to process, analyze, and learn from the vast amount of IoT data [23]. IoT usage is extremely prevalent in industrial settings, with one of the fastest-growing applications of the technology being in manufacturing and supply chain management. In smart factories, IoT sensors can identify and even predict mechanical problems to maintain seamless operations. They also gather and analyze operational data to identify the most efficient workflows and processes, which can then be automated through a centralized system [24].

Digital twins are digital representation of physical objects, processes, and systems. With digital twins, it is possible to represent real word things, such as buildings and factories. By receiving data from their physical counterparts, digital twins are able to simulate the physical entity’s performance, enabling preventive measures in the real world [25]. The process of digital twins is illustrated in Figure 2. Digital twins are dynamically changing, reflecting changes in their physical counterparts through the continuous flow of real-time data [26].

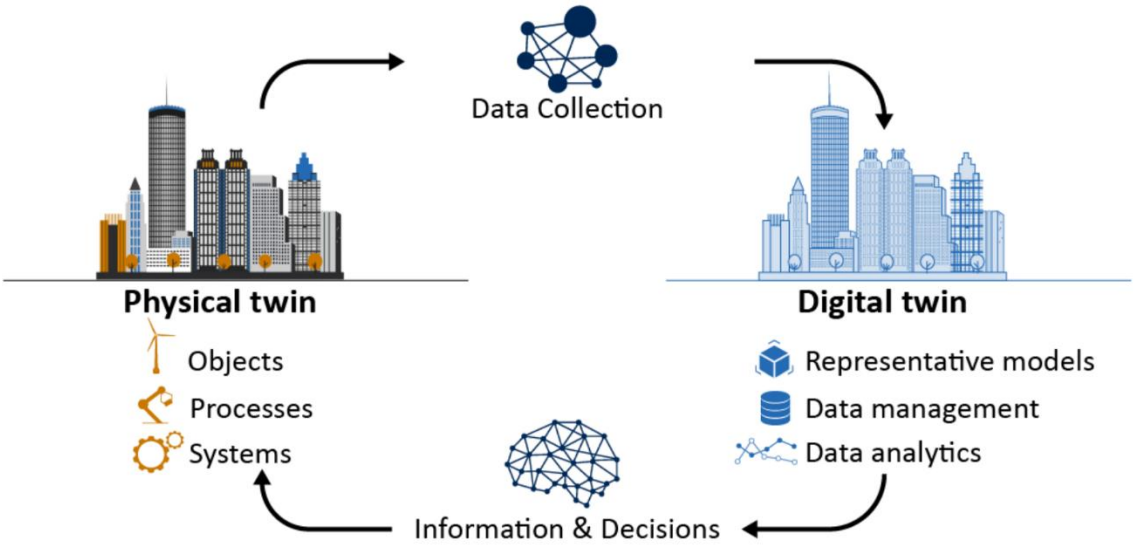

Figure 2. *Integration of the physical world and the digital twin* ***[26]***

Digital twins are based on many existing technologies. For example, IoT enables the collection of large amounts of data continuously from the physical twin through sensors placed in the physical environment. Moreover, cloud platforms play an important role of updating the digital twin with the latest state of the physical counterpart. The actual data analysis of the digital twins can be improved by the utilization of AI and machine learning. This enables testing of different scenarios and making predictions for the physical object [26].

There are many modern industries where the state of the art aspects of digital twins work extremely well, as illustrated in the paper by Sharma et al [27]. For example, in industries where the creation of physical prototypes takes times and requires plethora of resources, digital twins offer a more efficient and cost-effective alternative by enabling virtual testing and iteration. This allows an industries such as manufacturing to spend less resources on testing multiple different solutions, instead creating a more effective and resource-efficient solution. Another important use case highlighted in the paper by Sharma et al. are industries where the testing is extreme and cannot be conducted in laboratories. Digital twins offer a secure and accurate way to simulate real-world conditions, which is especially valuable in fields such as aerospace. They also give a significant edge to industries that depend on constant monitoring and fast responses by enabling continuous oversight of systems and early detection of possible problems [27].

Digital twins provide a plethora of use cases for the manufacturing industry with the industry exploiting this technology for creating substantial changes in its processes [28]. Through this technology, manufacturing efficiency can be improved, creating more state-of-the art products and improving the general operations. By modelling a manufacturing process, it is possible to acquire benefits related to equipment monitoring, simulations, and remote control of equipment. In addition, it is possible to better design the manufacturing process throughout the lifecycle, simulating each part of the process [28] The goal is to digitalize, streamline, and manage factories in a smarter and more efficient way. Digital twin technology supports this by giving manufacturers deeper insight into their operations, taking into account various aspects of the production process [28].

Digital twins are being utilized in various industries for improving production, test supply chains, and reduce costs [26]. One of these examples comes from BMW and its iFactory initiative. All of BMW's factories have been fully captured in a 3D scan, creating a digital twin that can be virtually accessed from anywhere. The aim is to design effective applications across all its production processes. These digital twins support BMW in reaching their sustainability and digital transformation goals [29]. Another example of digital twin utilization comes from Tata Steel, one of the largest steel manufacturing companies in the world. It is utilizing the benefits of digital simulation to establish better energy efficient practices across its operations, allowing the business identify opportunities for optimization before implementing changes in the real world [30].

2.2 Twin transition

The implementation of digital technologies in different sectors provides a path towards a sustainable future [5]. Twin transition is a term that refers to the green and digital transitions happening simultaneously, aiming to enhance sustainability goals through the use of digital technologies [10]. Figure 3 presents an illustration on what twin transition intends to achieve: finding the sweet spot where digital transition amplifies the transition towards sustainable practices.

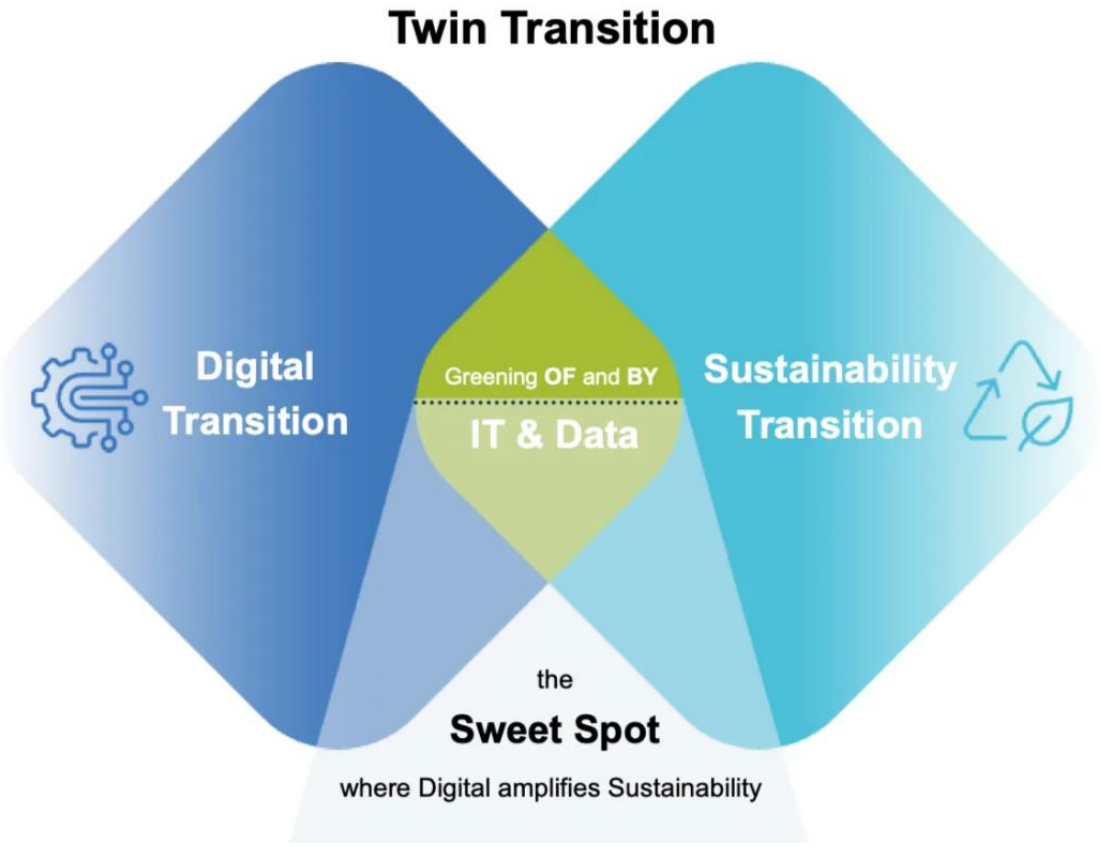

Figure 3. *Twin Transition* ***[31]***

Through the green transition, the goal is to achieve sustainability goals by mitigating the effects of climate change and combating environmental deterioration [10]. Green transition represents a radical change in the consumption and production patterns of humans, aiming for us to live within the planetary boundaries. This shift includes reducing the impacts of climate change by adopting eco-friendly habits and factoring environmental consequences into our decisions. Moreover, green transition provides an opportunity to transform today's unsustainable practices into a more equitable and sustainable future [10].

The European Union is at the forefront of global efforts in climate and environmental action, with several ambitious objectives outlined [10]. One of its biggest aims is the climate neutrality target by 2050. Moreover, the EU aims to achieve competitive sustainability, which encompasses being modern, circular, resource-efficient, and having a competitive economy [10].

The second important aspect of twin transition is digital transition. Generally, digital transition is defined as a gradual process of moving analog information into digital information, whereas digital transformation is seen as a wider concept that integrates digital

technologies in all aspects of an organization [32]. However, in the context of twin transition, digital transition is defined in a broad sense, referring to the ways in which digital technologies are modifying different areas like businesses, politics, and society [10]. This aligns well with the definition of digital transformation provided by Gong and Ribiere [33], who define it as “a fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders.” In this thesis, the term “digital transition” will incorporate the general definition of “digital transformation”.

Even though sustainability is a trending topic in the current world, the impact of digital transition for providing sustainability benefits requires further attention. [5]. Costa Melo et al. [34] focused on finding out how digital transition can affect Small and medium-sized enterprises (SMEs), especially focusing on digital transition’s impact on companies’ performance. This paper went through 74 papers from peer-reviewed journals and found out that mostly the focus was on improving the economic performance of the companies through DT. For example, 53 % of the companies in the study by Costa Melo et al. considered neither environmental nor social sustainability, with only 12% considering environmental sustainability, 26 % considering social sustainability, and only 9% considering both. Moreover, this stance is also shared by Xiao et al. [35], who argue that previous research has not sufficiently considered the environmental value that DT can offer, and mostly the focus has been on improving production efficiency.

Benefits of twin transition

For the EU, it is crucial to acquire the full value that the digital transition provides. Through a flourishing digital economy, the EU is able to gain economic while advancing the goals of the green transition [10]. Bocean and Vărzaru [5] looked at the impact that DT had on EU countries' economic and sustainability performance, finding that DT has a strong positive effect on both of them. The greater the intensity of DT, the greater the improvements in innovation, competitiveness, and entrepreneurship, which in turn drives stronger economic growth and sustainable development [5]. Digital transition can have a massive impact on enterprise green innovation, which focuses on advancing green technology and safeguarding the environment, enabling the successful balance of economic growth with environmental protection [35]. This enables the path towards an environmentally sustainable future that not only takes economic considerations into account but harnesses environmental benefits [35]. In addition, the research by Wang et

al. [36] states that the digital transition of enterprises has a strong positive impact of the green innovation in industry.

There are different functions of digital technologies that can have a positive impact on the environment with Muench et al. [10] presenting many of them in their paper. Through digital technologies, monitoring of key elements like material flows and emissions is enabled, which enhances the better use of materials and recycling. With digital simulations, information related to the full lifecycle of products can be received, allowing for improvements in production processes and minimizing the disruptions related to processes. For example, by analyzing production equipment in a predictive manner, the downtime of the equipment can be predicted, ensuring that production downtime is avoided. Technologies like artificial intelligence and digital twins allow the increase of production processes and more efficient management of systems. Through modern technologies, the potential for gathering and distribution information is unlimited. This information can reveal the full environmental impact of products or help calculate the gap between supply and demand [10].

While the green and digital transitions both have the ability to drive transformation across businesses, there are fundamental differences between them [10]. The green transition is driven from the need to reach the goals of climate neutrality and sustainability in a swift fashion, whereas digital transition is a continuous process looking to achieve technology-driven change. The differences between both can be seen from the fact that digital transition can also have a detrimental impact on the environment [10]. For example, digital infrastructure energy consumption is huge, with ICT responsible of over 2 % over global GHG emissions. In addition, the energy consumption of telecommunication and data centers will grow at a significant rate [37]. Therefore, it is crucial to link the green and digital transitions to fully realize the benefits that their synergies provide [10].

Other factors to consider in twin transition

It is not enough to only consider the technological and environmental factors when discussing the twin transition. Technology will play a role, but it is unlikely that the changes needed to succeed with the twin transitions will be solely technology-driven [10].

One of the pathways of looking at twin transition from a variety of different contextual factors is through the utilization of the PESTEL framework. The PESTEL is an acronym formed by the initials of six macroeconomic variables: Political, Economic, Social, Technological, Environmental and Legal.

Policies and political goals play a crucial role in advancing towards net-zero emissions and safeguarding the environment. The advancement and use of digital technologies is influenced by different standards, regulations, and policies that are implemented. As technologies advance, political frameworks need to be updated so that the values provided by the technologies can be utilized. For the goals of the twin transition to be reached, it is important that there is collaboration on a global and geopolitical level [10].

For many businesses, the costs related to moving towards a new technology represents a huge barrier for change, which creates a dependency on current technologies and systems. There needs to be an understanding of the long-term economic benefits that the twin transition provides. As green and digital technologies become more prevalent, the opportunities linked to them will grow, and they are able to provide novel business opportunities. Even though investments are being made into the green and digital economy, there is a need for increased financing in this sector. A lot of capital is still being directed towards the old economy that offers short-term gains but does not take into account the social and environmental long-term costs [10].

For twin transitions to succeed, there needs to be a clear social acceptance for the change because without societal commitment and behavioral change, the transitions will not occur. This requires a behavioral change from people and the acceptance that the transition towards a sustainable economy is in the best of interests of the society. Moreover, there needs to be an acceptance of the new technology by the people, which is usually gained when the technology is easy to use and provides benefits in everyday life. The transitions have to be fair for everyone, which means that the benefits gained from the transition are available for all. Fair transition also takes into account the ethical worries linked to technologies such as artificial intelligence [10].

Legal factors examine how laws and regulation impact a business and define what is allowed in the region that the business operates [38]. From the twin transition perspective, it is crucial that legal aspects are considered. For example, considering the legal frameworks related to environmental laws, which require businesses to comply with certain carbon emission related targets. Moreover, as data has become a huge part of this process, it is crucial that data protection regulations are taken into account [38].

Impact of different sectors

If the EU desires to reach its climate targets, reductions in the industrial sector will be key, with the industrial sector currently responsible for around 20% of the GHG emissions

in the EU [10]. Novel technologies will play a huge role in the reduction of GHG emissions. Solutions like the Internet of Things are able to supply real-time data related to energy usage, enabling industries to optimize the way energy is used. Moreover, a technology like digital twin enables simulation and forecasting, which can be leveraged to pick the optimal green materials [10].

The paper by Muench et al. [10] provides a case study related to data-driven materials optimization. Through the optimization of materials, materials can be used longer, their recycling rates can be increased, and low-carbon replacement materials can be designed. Digital technologies significantly reduce the time required to develop novel materials and plan their optimization. For example, through the use of AI, promising material design solutions can be picked swiftly, especially when dealing with lot of options. Additionally, digital twins create highly accurate virtual models that can simulate material properties, investigate new material alternatives, and assess performance across the entire lifecycle of a material [10].

In addition to the industrial sector, other sectors that emit the most GHG in the EU include energy, agriculture, buildings and construction, and transport and mobility [10]. All of these sectors can limit their environmental impacts by utilizing technologies like IoT, AI, and digital twins that enable the use of data in myriad of different ways. One of the most common ways of moving towards a climate-neutrality is the utilization of as-a-service methods [10]. As-a-service models are based on providing an end-user with a service that does not require the user to own that specific product [39] This can be seen in transport through mobility-as-a-service (MaaS). MaaS is a digital platform allowing a customer to have access to various transportation methods in real-time [10].

2.3 Data economy

Recent years have seen a huge increase in the digital transition sector with digital technologies revolutionizing the economy and society [7], [40]. This transformation is spearheaded by data [7], resulting in the generation of huge amounts of data that enables novel opportunities for organizations to monetize data [40]. Data economy can be defined as “the expanding economic activity centered around data collection, analysis, and sale” [40]. The benefits provided by data will be apparent in all facets of life, and it is something that will transition the way humans produce, consume and live. The great

thing about data is that it is an economic resource that can be replicated near zero cost, and it can be utilized simultaneously by multiple parties [7].

The EU has the capability to realize the values of a data-agile economy, as it has the technology, the knowledge, and the proficient workforce [7]. However, it is crucial to continue the innovation related to data, as the field is evolving constantly and has huge competition from the likes of China and the United States [40]. Moreover, China and the United States demonstrate a higher maturity related to data economy compared to Europe, as they are better at creating digital business models related to data usage [41].

Data is a vital aspect for economic progress to occur. Through data, many new products and services can be established, enabling businesses to enhance their productivity and resource efficiency [7]. Businesses have understood the immense significance of the data that they gather and its potential applications in many of their operations. For example, data acts as a major resource for making strategic business decisions for growth- [40]. In addition, for up-and-coming businesses and SMEs, data acts as a crucial resource for the development of products and services

Data sharing offers advantages that extend beyond individual organizations. [42] De Reuver et al. [42] argue that data sharing through the supply chain can lead to collaborations and coordination, leading to the development of novel products and services. For sustainability purposes, data may be shared in the form of a digital product passport, which provides detailed information related to the product. Through this kind of shared data, it becomes easier to plan processes and increase accountability related to sustainability actions [42]. Through inter-organizational data sharing, businesses get access to novel data sources, which inevitably will break down data silos and give access to data that previously had limited access. Moreover, as companies collaborate together, they are able to enhance data standards thus improving the quality of the overall data [43].

The EU realizes the potential value of data sharing and has thus established a legal framework called the Data Act, which becomes applicable on the 12th of September 2025 providing a legal framework of data access and utilization. The aim of the Data Act is that companies should make their data more easily accessible. Moreover, this framework enables to increase data-driven innovation while making sure that all actors in the data economy ecosystem derive benefits from the data [44].

Problems related to data

Although data and its sharing offer tremendous value to companies, there are fundamental problems that data presents. According to Sestino et al. [41], one of the biggest concerns is related to privacy, with individuals and companies being increasingly worried what can be done with their private information. There is the risk that data is utilized for surveillance or other intentions that violate the rights of the individual. Addressing the concerns related to data privacy guarantees that the data economy is fair and safeguards the rights of individuals and corporations [41].

Recent years have seen an enormous growth in the data amount of companies. However, most of this data remains unused and inaccessible to companies for gaining business value, resulting in what is known as dark data. [40] Dark data is be described as "the information assets organizations collect, process, and store during regular business activities but generally fail to use for other purposes" [40]. The value of dark data is immense, which is emphasized by a research study. According to this study, a moderate size Fortune 100 business can boost their revenue by 2 billion dollars by just 10 % improvements in data usability and remote access [40].

Gaining access to data can be a big challenge for companies [45]. For example, when companies share their data to other companies, the receiving company may be able to create business values from this data and perhaps enhance their operations. In this case, the company sharing their data will be wary of distributing information outside the corporation, as it allows other companies to utilize this information for no cost. Providing unrestricted access to such data would undermine the incentive for companies to investing in producing and maintaining such data [45].

Even when data is shared between stakeholders, there are huge interoperability issues linked to incorporating data that comes from different sources. There is a need for standard formats and protocols for collecting and processing data from distinct sources in a compatible manner [7]. While data sharing can provide plenty of benefits, these benefits require that the quality of the shared data is sufficient, so it must be ensured that the data is reliable, accurate, and suitable for use [43].

2.4 Production efficiency

Productivity can be seen as a metric of economic performance that measures the amount of output of goods and services that can be produced relative to the amount of inputs used. The greater the increase in output compared to input, the bigger the increases in

productivity [46]. Generally, productivity concepts can be divided into two categories. Firstly, labor productivity compares the amount of output to the amount of labor that is required to produce it. In addition, there is multifactor productivity that compares output with combined inputs, usually consisting of both labor and capital inputs [47].

Over the past few decades, EU countries have faced a sharp decline in economic growth, with one of the main reasons being a significant drop in productivity growth, particularly in labor productivity [48]. For a long time, aggregate labor productivity growth has been going downwards in the EU. As seen from Figure 4, there has been a steady decline in the labor productivity growth, with the annual growth declining from 7 % in 1960s to only 1 % since the 2000s [49]. The growth rate of labor economy is a fundamental factor in growing the overall economy and advancing high-quality developments. [50].

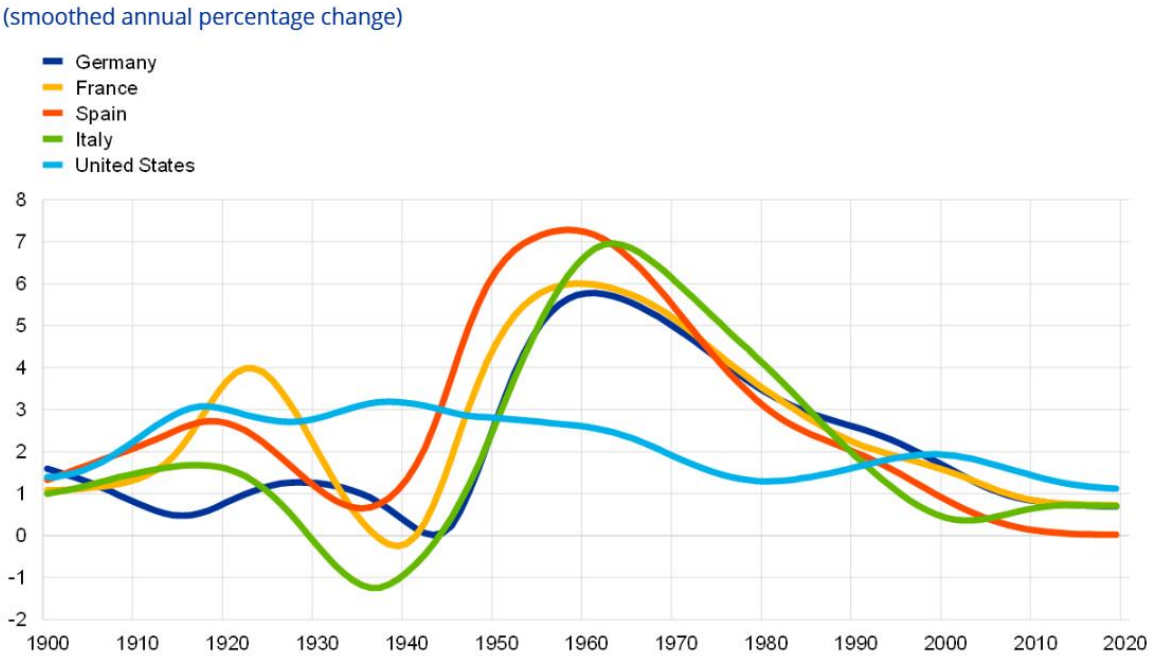

Figure 4. *Labor productivity growth in some of the major economies* ***[49]***

There is strong evidence to suggest that the digitalization of businesses is able to enhance productivity of businesses. The paper by Song et al. [50] shows that through digital technologies, businesses are able to improve their production efficiency and also spread their innovations more easily. Moreover, Quintano et al. [51] state that through the utilization of digital technologies, businesses reduce costs and become more efficient. In addition, research conducted by Gal et al. [48] shows strong evidence that general digital adoption is linked to productivity gains at a firm level. Moreover, a recent study by the

Organization for Economic Cooperation and Development (OECD) shows that 10% increase in industry-wide adoption of cloud computing is affiliated with an average 3.5% increase in productivity [52].

However, it is important to note that digitalization alone will not necessarily lead to increases in productivity benefits. To acquire the benefits from digitalization, companies need to create the right environment by increasing the human capital skills related to digitalization, like software and data knowledge [51]. This is also affirmed by Gal et al. [48], who state that productivity gains are hindered by weaknesses in skills and occupational shortages. Moreover, the productivity gains related to digitalization are higher in more technologically advanced businesses [51].

2.5 Collaborative asset lifecycle management

Asset is an item, thing or entity that brings concrete value to a business. The value that the asset provides varies significantly between different organizations and may be tangible or intangible, financial or non-financial. Asset Lifecycle Management (ALM) is the pursuit of businesses for realizing value from their assets, in order to achieve their business targets. Organizations must manage and oversee their assets effectively to unlock value by balancing risks and opportunities, while achieving the optimal trade-off between cost, risk, and performance [53].

Through ALM, the aim is to coordinate the different processes related to an asset throughout its lifecycle [54]. There are several benefits that ALM presents for businesses, including improved financial performance, advanced organizational decision making, and improved services and outputs [53]. There are multiple drivers that impact the goals of a company's asset life cycle management. These include resource efficiency, sustainability demands, and productivity improvements [55]. For capital-intensive industries, like the forest industry, it is crucial to adapt ALM principles, as these industries entail high-values assets and huge capital expenditures [56].

According to [57] , digital transition has considerable implications for asset management and can lead businesses to reconsider their procedures throughout the asset lifecycle. By looking at these implications, businesses are able to achieve better use of their assets with the aim to get the best value out. For example, digitalization enables better data related to assets, connects different stages of the asset lifecycle, and boosts information distribution between companies [57]. This is corroborated by Kortelainen et al. [55], who

state that digital transition has a significant impact on the asset management processes of a business and provides solutions for improving the practices related to ALM. Data related to assets is at the center stage of optimal maintenance and asset management, reiterating the importance of a clear data strategy [57].

With digital technologies, it is possible to collect real-time data and conduct precise key performance indicator (KPI) analysis, which leads to predictive maintenance and predictive analytics [57]. Moreover, these tools advance collaboration between businesses and create beneficial insights over the asset lifecycle. Through these insights, it is possible to push constant improvements, enhance asset performance, and reduce asset downtime. Having the access to the correct type of data is crucial and will provide businesses with plethora of benefits. Businesses must evaluate the cost of acquiring data against the potential cost of not having access to the relevant data [57].

To obtain concrete value from asset data, it is important to utilize advanced analytics techniques like big data analytics and machine learning to recognize patterns and potential failure points in assets [57]. These technologies enable filtering of vast array of data to find relevant signals that indicate potential failures in assets, enabling predictive maintenance of assets [57]. Another important technology is edge computing, which enables the distribution of real-time insights directly to maintenance technicians and machine operators [57].

Digital twins provide a digital representation of an asset throughout its lifecycle. According to Ammermann [58], by getting a real-time access to the asset, it is possible to detect any problems related to the asset and continuously improve the asset performance. Digital twins also provide details related to the health of the asset and the remaining lifetime information, which enables enhanced predictive maintenance operations [58].

ALM best practices

The main objective of asset lifecycle management for businesses is to get the maximum value of assets throughout their lifecycle. To acquire these benefits, it is important that businesses incorporate the best practices related to ALM in their operations.

Adopting digital solutions is a foundational best practice in asset management, enabling organizations to optimize asset performance throughout the entire lifecycle. Unlike manual tools such as Excel, specialized asset management software provides automation, scalability, and advanced capabilities that support proactive decision-making [59]. These tools centralize critical information, ensuring that data is easily accessible and facilitating informed, data-driven decisions at each stage of the asset lifecycle [60]. A centralized

system for asset management not only streamlines operations but also reduces the likelihood of data loss or duplication, thereby improving asset visibility and control [60].

Through predictive maintenance, it is possible to minimize the risk of unexpected breakdowns related to machines, saving both time and money. At the same time, optimal predictive maintenance will lead to lifespan extensions of assets and operational efficiency improvements [61] By implementing a clear and proactive preventive maintenance strategy, organizations can ensure that all assets remain in optimal condition, which in turn extends their lifespan and usefulness [62].

Tracking and analyzing key performance indicators (KPIs) is essential to successful asset management. Organizations must continuously monitor asset performance and utilization to identify underperforming assets or those not delivering expected returns [60]. Without clearly defined KPIs, achieving business goals becomes challenging. Therefore, establishing relevant asset management metrics offers a structured pathway toward continual improvement and achievement of business targets [63].

Optimal ALM, requires continuous improvements of processes. Regular assessments of existing practices is crucial and include steps like reviewing current ALM practices, focusing on new technological developments, and making necessary changes in business needs if required [60]. Encouraging a culture of continuous improvement helps businesses stay alert for new opportunities and challenges that arise [63]. Part of this continuous improvement is timely upgrading of assets. A best practice is to define specific asset behaviors that signal it is time for an upgrade, thereby minimizing downtime and enhancing efficiency [63].

2.6 ERP

Enterprise Resource Planning (ERP) is a software system that manages all the different functions of a business by connecting them to a single integrated system. An ERP system is based on distinct modules that are connected through shared database, allowing different applications talk to each other. These modules work collectively to advance the business goals of an organization [64]. An ERP system provides a business with a single source of truth, enabling different sectors to use accurate organizational data. [64] As shown in the Figure 5, there are multiple parts within an ERP system, and ensuring the precision of the data within the system is crucial. Different business actors will use ERP in distinct ways. For example, finance requires ERP to swiftly close books, and sales will use an ERP to manage customer orders [64].

Figure 5. *Different parts of the ERP system* ***[65]***

SAP SE is a German multinational software company specializing in enterprise solutions [66]. Through its integrated applications, SAP enables businesses to connect different parts of their operations into a fully digital platform. SAP offers over 100 solutions that cover all the necessary business areas of a company [66]. The flagship solution of SAP is the SAP ERP software. This solution is the most widely used ERP system in the world, with approximately 40 000 companies utilizing it across 120 countries [67].

In addition to ERP, SAP offers many other solutions, such as SAP Ariba, a cloud-based B2B marketplace for procurement and supply chain management, and SAP Success-Factors, cloud-based human resource software [68]. Moreover, SAP offers the business technology platform (BTP) that combines application development and automation, data and analytics, integration, and AI capabilities into one united environment. This platform allows businesses to create, integrate, and extend applications by utilizing cutting-edge technologies [68].

SAP BNAC

The growing amount of data intelligence enables organizations to make superior decisions more swiftly and allows processes to be more effective and resilient. In asset management, there is a clear advantage to be gained from cooperating with different stakeholders based on a single version of truth. By converting a disconnected asset lifecycle into cohesive and efficient processes for all collaborators, organizations can achieve greater resiliency and transparency across the lifecycle of the asset. [69]

The SAP Business Network Asset Collaboration (BNAC) is a cloud-based asset management network that enables collaborative asset management between different stakeholders in asset-intensive industries [69]. Figure 6 presents some typical stakeholders in the collaborative asset lifecycle ecosystem. Original Equipment Manufacturer (OEM) suppliers are in charge of enhancing quality of service and decreasing costs, which requires cooperation with other suppliers and operators [70]. Asset operators are looking to increase equipment efficiency and uptime by improving performance and speeding up maintenance and commissioning processes. In addition, service providers are able to improve their services when cooperating with asset operators constantly across the lifecycle. Such collaboration leads to fewer errors, reduced accident frequency, and enhances productivity [70].

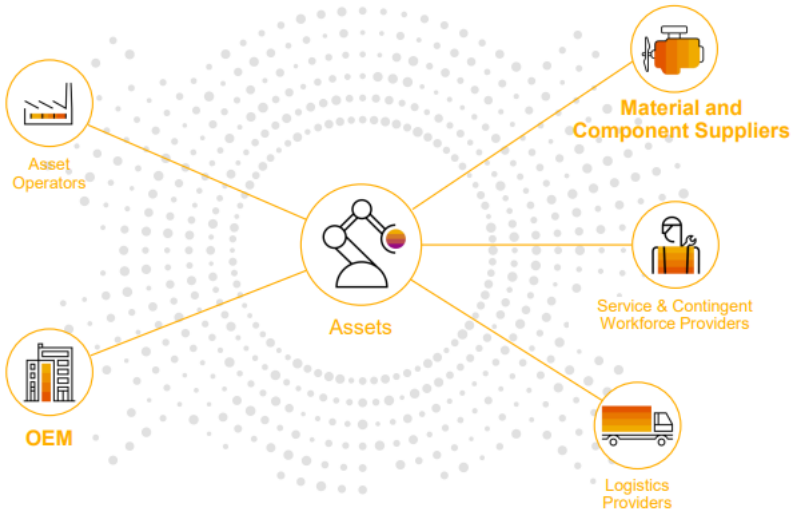

Figure 6. *Different stakeholders in BNAC* ***[70]***

Table 1 presents the four key areas of SAP BNAC presented in [71]. Firstly, BNAC provides distinct identification for each asset, which enables to preserve consistency, completeness, and correctness for the assets. Secondly, the BNAC platform brings together

different stakeholders to a collaborative ecosystem. This allows the sharing of different kinds of information related to assets, with the vision of prolonging the life span of assets. Thirdly, the platform allows the sharing of latest data related to assets. Data streaming of asset data across the ecosystem requires sensors and other data transfer technologies. This facilitates the transition towards a predictive maintenance approach that enables the early detection of issues and proactive resolution. Finally, SAP BNAC works closely with SAP BTP. Through the BTP technology environment, the BNAC platform is able to get access to the latest asset information [71].

Table 1. *Key areas of SAP BNAC*

Category	**Description**
Content	Asset identification
Network	Collaborative ecosystem
Applications	Data sharing and predictive maintenance
Integration	BTP integration

One of the examples of a business utilizing SAP BNAC has been Endress+Hauser [72]. The company is a measurement technology company that serves many customers with many of them operating complex manufacturing plants. Many of these customers faced issues with their enterprise-centric systems which were not designed for interorganizational collaboration. Some of these issues included lack of asset standardization and asset definitions, and siloed supply chain processes. [72].

To address these challenges, Endress+Hauser adopted BNAC and BTP, helping customers enhance collaboration across the asset lifecycle and tap into the full potential of digital technologies [72]. According to the Business development Manager of Endress+Hauser, these solutions have supported their customers in project collaboration throughout the entire lifecycle of an asset, gaining valuable information related to their applications [72].

The customers of Endress+Hauser have gained many concrete benefits from the utilization of BNAC and BTP. Firstly, the time used for processing asset documentation has dropped significantly. Moreover, the electronic handover of the solution empowers immediate data sharing, saving both costs and resources. In addition, through BTP's automated master data integration, the customers have been able to reduce the time required on searching and arranging information. On average, this can save up to an hour per site visit and prevent errors that could lead to costly downtime [72].

3. RESEARCH CONTEXT

This section provides information related to the target company of the thesis and illustrates their current issues related to data sharing in the production environment. In addition, the research project that this thesis is closely linked to is presented.

3.1 Metsä Group

By managing assets effectively, organizations can acquire tremendous potential for their businesses. In the context of Metsä, asset management refers to identifying, monitoring, and maintaining all the systems and equipment in the mill area, with over 30 production mills currently in operation.

In Metsä Group's production processes, assets encompass a wide range of equipment, including pumps, motors, production machinery, vehicles, and IT devices. Given that a certain mill has thousands of different asset types, managing them effectively without a suitable information system is not possible. As a result, efficient asset management serves as a key enabler for optimizing production processes across Metsä's mills.

In 2021, Metsä Group started a big overhaul and harmonization of its ERP systems [73]. This project, called ERP +, aims to establish common processes across businesses areas, resulting in united, modern, and standard system solutions. Previously, all the business areas utilized their own ERP solutions; however under the new solution, all the business areas will be part of a single, unified ERP solution, S/4HANA. For the ERP + project, Metsä has conducted data harmonization related work related to production assets with common data standards and processes created.

The current issue is that, although the data work related to assets has been completed, there is no standardized solution in place for exchanging asset data related information with external stakeholders. Currently, the data exchange takes place manually through Excel files. Excel requires manual creation and adherence to standardized templates, making it prone to human error. Moreover, the collaboration is manual and does not encompass real-time collaboration features. In addition, Excel also has limited integration capabilities with other company systems. This is why Metsä is looking for a digital solution for exchanging asset-related data with different stakeholders in the production environment. This would ensure standardized data formats, seamless collaboration and

reduced errors. This kind of solution would also be able to integrate with already existing systems like the ERP system of Metsä.

As the projects of Metsä happen on a large scale, there is a large amount of data related to each of them. That is why all the data created in new investment projects of Metsä must follow general guidelines and standards set internally. When collecting data from suppliers, it is important to make sure that this data gathered complies with standard templates provided by Metsä.

3.2 Colife

The Colife project was initiated from the request of industries for creating robust and sustainable collaboration practices based on data sharing across the lifecycle between different stakeholders in the asset process. Businesses have indicated that the proficiency required for the topic is lacking at the Finnish or European level, with one of these companies being Metsä Group [11].

Better utilization of data economy principles enables capital-intensive industries like forest, process and energy to create new business value and improve their production efficiency [11]. Businesses require a fair and trustworthy model for co-operating in the field of life cycle services. Main objective of the research project is to create a Colife concept, a playbook for fair data economy in industrial asset management ecosystems [12]. It will provide guidance on utilizing digital information in collaborative asset management, utilizing data in asset management ecosystem for the creation of business value, and deploying data management technologies in the ecosystem. This will result in a scalable approach for asset management practices that can be utilized across several industries [11].

The project is divided into different categories with the beginning part focusing on understanding the needs and capabilities of industrial stakeholders to operate in a sustainable asset management operating environment. This understanding will be developed through interviews with industrial companies [11]. The author of this thesis will be part of these interviews conducted in the Colife research project.

4. RESEARCH METHODOLOGY

This chapter presents the research methodology of the paper. Section 4.1 goes through the research methods utilized in this paper and why they were chosen. Section 4.2 presents the interview background for the first part of the research. Section 4.3 outlines the second part of the research related to the digital tool analysis.

Research methodology can be described as a roadmap that helps the researcher to conduct the research and stay on track by limiting the research scope [74] . Moreover, it depicts the approaches chosen for information identification and analysis. A research methodology encompasses the crucial components of a study, including research design, data collection methods, data analysis methods, and the overall framework within which the research is executed [74]. Figure 7 illustrates the research methodology that is utilized in this thesis. The research was a qualitative research that utilized the case study strategy for answering the research questions. Moreover, the two data collection methods chosen were interviews and analysis of existing material. In a research, it is vital to illustrate why certain methodological choices were made and why these are the best ways to get the answers to the research questions [74]. The choices for this methodology are clarified in the following chapter.

Figure 7. *Research methodology*

4.1 Research methods chosen

Research methodology can be divided into three separate categories. Firstly, there is the quantitative methodology, which emphasizes the collection and testing of numerical data. This kind of an approach enables the creation of correlations between variables, constructing predictions, and creating generalizations. The quantitative approach is well suited when the aim is to gather large amounts of data swiftly. Secondly, there is the qualitative methodology, which aims to understand the subjective opinions and experiences of people [74]. In qualitative research, the goal is to gather in-depth knowledge related to a certain context [75]. This approach requires less participants but can be more time-consuming, as time spent with each participant is considerable [74]. Thirdly, there is the mixed-method methodology, which combines aspects of both quantitative and qualitative approaches. This method can enable obtaining a more complete picture of the problem [75].

As this thesis is aiming to get an in-depth knowledge related to the unique context of production ALM and interorganizational data sharing, a qualitative research approach fits well in the context of this research. The aim is to study data sharing in the context of the forest industry and especially applied to the target company, so the qualitative approach is the one that makes the most sense.

Once the qualitative research methodology has been chosen, it is imperative to pick the right research design that aligns with the study. The research design acts as the plan on how the research will be conducted [75]. One common design method is the case study, which [75] describes as “a detailed study of a specific subject in a real-world context”. In a case study, data collection can be conducted using several sources and methods [75].

For this thesis, an embedded case study is the chosen design method with the primary focus being on Metsä Group and finding concrete ways for improving their production processes utilizing digitalization. What makes this study embedded is the fact that it incorporates insights from other actors in the production process ecosystem, with many of them being partners of Metsä.

For a case study, there are many data collection methods that exist, for example, interviews, observations, and analysis of existing data [76]. The data analysis of this research was conducted by two distinct data collection methods: semi-structured interviews, and analysis of existing data.

The first research question: “What influences a company’s decision to take part in a data-sharing ecosystem within the collaborative asset lifecycle business?” is looking for an in-depth exploration of different companies in the production ecosystem with the aim of getting knowledge from key personnel from different businesses. This is best done in the form of interviews, and thus interviews were chosen as the primary data collection method for the project. The interviews consisted of the target organization, Metsä Group, and alongside that, there were interviews with the rest of the companies in the research project Colife.

For the second research question: “What are the technologies that can be used to enhance data sharing in collaborative asset lifecycle solutions?” utilized interviews as the main tool for gathering insights, supplemented by a comparison to the existing literature. Through these interviews, perspectives from various companies on emerging technologies and their effectiveness in production processes was collected. These insights were then analyzed alongside findings from the literature review, allowing for a comprehensive evaluation of technological advancements in collaborative asset lifecycle management.

The third research question: “How to concretize the benefits of shared asset data from sustainable development and production efficiency perspective?” is looking to find an existing digital solution for Metsä Group that will optimize their production processes through the utilization of shared data. For this part, material analysis of an existing data transmission platform was conducted, to find out whether there is an existing solution that aligns with their sustainability and efficiency objectives.

4.2 Interview background

The interviewed companies in the project were: Core Link, Etteplan, Kiwa, Metsä Group, Nokia, Nortal, and SAP. These companies perform a diverse set of tasks within the production ALM ecosystem. Figure 8 presents the different roles that the interviewed companies take in ecosystem. Firstly, there is the industrial customer that uses and manages assets in their production environment [11]. Production asset manufacturers are in charge of producing assets or asset components for the industrial customer. Maintenance service providers are able to give different maintenance services for the industrial customer. In addition, supportive service can give distinct services in the production environment. For example, providing engineering solutions, data related services, inspection services and solutions for asset management. Finally, ecosystem and infrastructure

providers provide cloud-based services and other tools for the management and operation of the ecosystem [11].

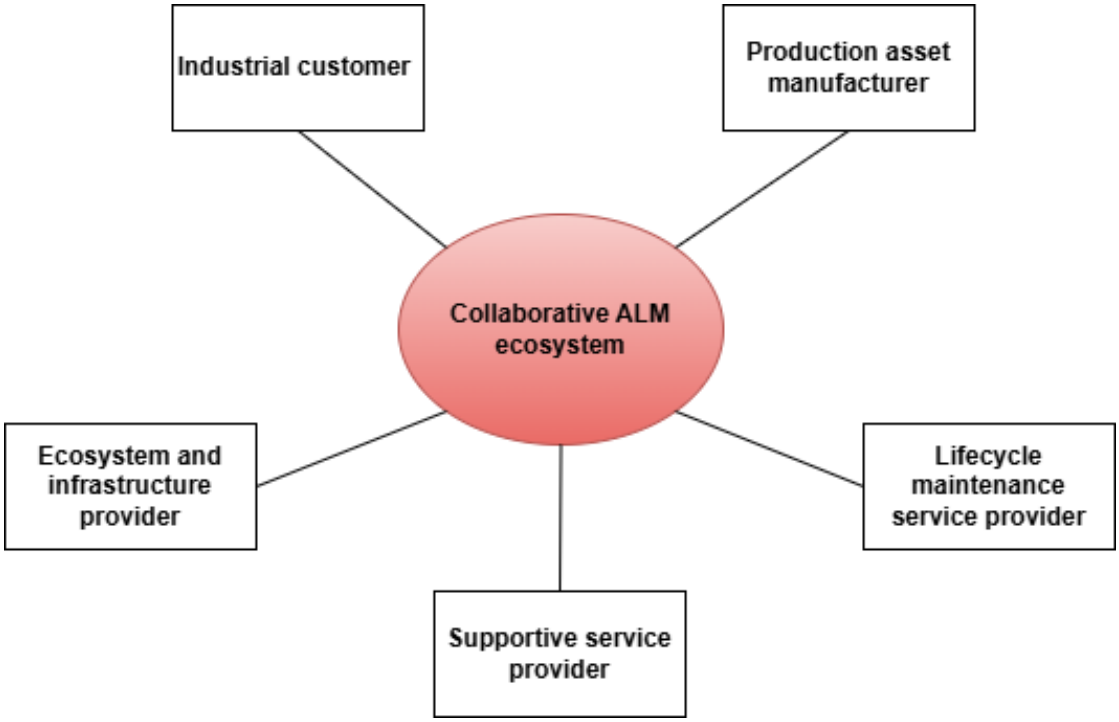

Figure 8. *Different stakeholders in the production ALM ecosystem* ***[11]***

The interviews were held on Microsoft Teams with 1,5 hours allocated for each session. Before the interviews, company representatives received a template containing the interview questions, allowing the interviewees to familiarize themselves with the themes of the interviews. Most interviews consisted of 1-2 people from each company, and the predominant roles of interviewed personnel were related to strategic decision making, and business process development. In addition, the interviews included personnel with expertise in technology.

As the interviews were semi-structured, there was flexibility during the discussions, and it was more important to get important insights rather than get an answers to each question in the questionnaire. The main parts of the interview, can be divided into three distinct categories . Firstly, there is **data sharing and value.** This part looked to find out what kind of data is relevant for businesses in the ALM, what are the business data needs, and what kinds of bottlenecks exist in data sharing. The next part looked at the **business opportunities**: what kind of business opportunities do companies think that data sharing provides, what are the new services/process innovations that could be created and what is needed to reach these goals. The final part looked at the **sustainability**

viewpoint, to find out what are the sustainability effects on production ALM, how to take sustainability into account and what are the benefits that sustainability provides.

4.3 Collaborative asset management tool analysis

The second part of the research focused on looking for a digital solution that enables collaborative data sharing in the production environment for the industrial customer that is Metsä Group. The company wishes to find an existing solution that exists and integrates seamlessly with their existing digital systems.

The primary ERP solution utilized across Metsä's operations is SAP's system, and the company is currently in the process of integrating a unified S/4HANA solution across all its business areas. This is why the company wants to find a solution that integrates with the SAP ERP system. SAP offers an existing solution, BNAC, for collaborative asset management, which also integrates seamlessly with SAP's ERP system . BNAC is a tool that has potential to enhance collaboration between stakeholders and improve production processes through shared data.

This thesis went through the general features of SAP's cloud-based BNAC solution to find out whether this solution could enable collaborative asset management between stakeholders and present concrete benefits from the perspective of sustainable development and production efficiency. The analysis also focused on understanding how the solution solves the challenges related to data and data sharing that businesses face, which inhibit businesses joining a collaborative ecosystem. The analysis of BNAC was conducted through the existing material related to the solution, which consisted of general documentation related to the solution along with detailed technical documentation.

5. QUALITATIVE INTERVIEWS FROM COMPANIES

This chapter goes through the results obtained from the interviews with Section 5.1 presenting general insights captured from the interviews, Section 5.2 presenting the ambition & opportunity levels of the interviewed businesses from the twin transition perspective, and Section 5.3 summarizing the insights and presenting the key aspects that companies require for a collaborative data sharing ecosystem to take place.

Through the interviews, the roles of the companies in the production ecosystem became apparent with the roles of the different companies in the production ALM presented in Table 2. As can be seen from the table, the interviewed companies are conducting a diverse set of tasks in the ecosystem, which will provide a holistic view of the needs of companies in the ALM ecosystem.

Table 2. *Companies and their roles in the production ALM ecosystem*

Company	**Role**
Core Link	**Production asset manufacturer** **Maintenance service provider** **Supportive service provider** • Inspection services • Engineering & consulting
Etteplan	**Supportive service provider** • Engineering and consulting • Data management & analytics • Asset management solution provider
Kiwa	**Supportive service provider** • Inspection services • Engineering & consulting
Metsä Group	**Industrial customer** • Capital intensive industrial company
Nokia	**Ecosystem and infrastructure provider** • Ecosystem coordinator • Infrastructure service providers
Nortal	**Supportive service provider** • ERP/MES solution provider • Data management & analytics • System integration service provider **Ecosystem and infrastructure provider** • Ecosystem coordinator
SAP	**Supportive service provider** • Asset management service provider • ERP/MES solution provider • Data management and analytics

5.1 General insights

Ambitions and goals

Companies see that a collaborative ALM ecosystem provides plethora of benefits that need to be seized. One of the big drivers mentioned by companies was the goal of moving towards a sustainable society. Interviewed businesses see that through a collaborative data sharing process and the use of novel technologies, production processes can be optimized and made into more energy efficient, which will lead to mitigating the effects of climate change.

Another clear ambition for businesses is to acquire businesses opportunities provided by data sharing. Data is a key part of the interviewed businesses, and they want to get the maximum benefits that it provides. Moreover, many businesses are eager to receive data from different stakeholders that would provide them with valuable and actionable insights for improving their businesses.

Interviewed companies are open towards joining a collaborative ALM ecosystem and see that a common data platform is something to strive towards. The interviewed companies share a common belief that an asset collaboration platform fosters ecosystem-wide engagement by enabling operators, OEMs, and service providers to seamlessly connect through an open network—driving greater efficiency and promoting a collaborative ecosystem. This kind of ecosystem does not only improve the processes of the participants but also leads to co-learning and sharing of best practices throughout the network.

Biggest challenges in production ALM business

To realize value from data, it needs to be available, organized, and accurate. Currently, there are many challenges related to production ALM that bother the interviewed business representatives. Firstly, many companies find that data is disorganized, scattered, and unreliable, making it difficult to obtain any value from the data. One business mentions the fact that they have so much raw data available, that it becomes challenging to put all of it in the correct format. Data quality issues are significant, with one business representative emphasizing the importance of data standardization to get the benefits from edge technology. This also applies to machine learning, which requires data to be in correct format.

At the same time, it is difficult for businesses to get access to relevant data related to production processes and asset management, as there is a lack of clean and structured

data sharing happening between stakeholders. Lack of common data sharing solutions leads to data silos and restricted access for many parties within the ALM ecosystem. Moreover, in complex production environments with many organizations, it becomes important to have a common solution. Currently, many businesses are utilizing varying ways of sharing data with only a small amount supporting standardized protocols. Without up-to-date information on asset conditions, it becomes increasingly difficult to optimize asset usage throughout the lifecycle. Another concern for the interviewed businesses is that the value of data is not seen throughout the organization. Many key people inside businesses do not see the concrete value that the data provides, which results in lesser resources being allocated to data-related practices.

The biggest bottleneck in data sharing that all companies mention is the hesitancy of stakeholders to share data. One of the reasons for this hesitancy is the value provided by data—raising the question: will companies be open to sharing data that provides an advantage to them? This especially applies to businesses where data is a key component. For example, many OEMs are apprehensive about joining data-sharing platforms, as there is a fear of losing their service-based offerings to an external platform. Another hesitancy for data sharing comes from the fact that the company is not able to control what happens to the data once it is shared, with companies wanting to make sure that the data does not end up in the wrong hands. Additionally, businesses are wary of sharing data with their competitors, not wanting to share any critical information.

Sustainability

When asked about the positive effects that sustainability can bring into production ALM, most companies mentioned that by taking sustainability considerations into account, the lifecycle of an asset is planned better at each stage of the lifecycle. This leads to a better utilization of assets with assets gaining a longer lifecycle and enabling circular use of assets. Moreover, by using assets effectively, costly investments in new assets can be avoided, which also reduces the environmental impact of integrating new assets to the environment. Importantly, the data related to sustainability and environmental performance also plays a massive role. To achieve sustainable asset lifecycle, it is imperative that there is transparency of data across the lifecycle.

Sustainability considerations also bring challenges for businesses in the production ALM environment. One of the biggest issues is the balancing sustainability actions with the financial motivations. Especially at the start, there will be additional costs that make com-

panies wary of taking actions related to sustainability. In many asset heavy environments, carbon emission mitigation requires process revamps and the replacing of assets. This means that underlying digitalization needs to be resilient and flexible in relation to the changes happening.

5.2 Twin transitions ambitions and opportunities

To get a better understanding of the twin transition ambitions and opportunities of the interviewed companies, this thesis will utilize a framework called the quadrant framework. This framework categorizes entities based on two intersecting dimensions, resulting in four quadrants with an unique combination of the two dimensions. In this thesis, the two dimensions will be ambition and opportunity.

Figure 9 presents a quadrant that places all of the six companies interviewed and places them based on their ambition level of reaching the goals of twin transition and based on the opportunities that each company has to go towards the twin transition goals. The top-right quadrant reflects companies with both high ambition and strong opportunities. The top-left quadrant represents companies with high ambition but fewer opportunities. The bottom-left quadrant shows companies with neither ambition nor opportunities, while the bottom-right quadrant includes those with opportunities but limited ambition.

All six companies were found to align closely within the top-right quadrant, sharing a similar outlook toward the twin transition. As such, they are collectively represented with a single marker to emphasize the overall pattern rather than highlight individual positioning. This approach also supports a neutral and generalized interpretation of the findings.

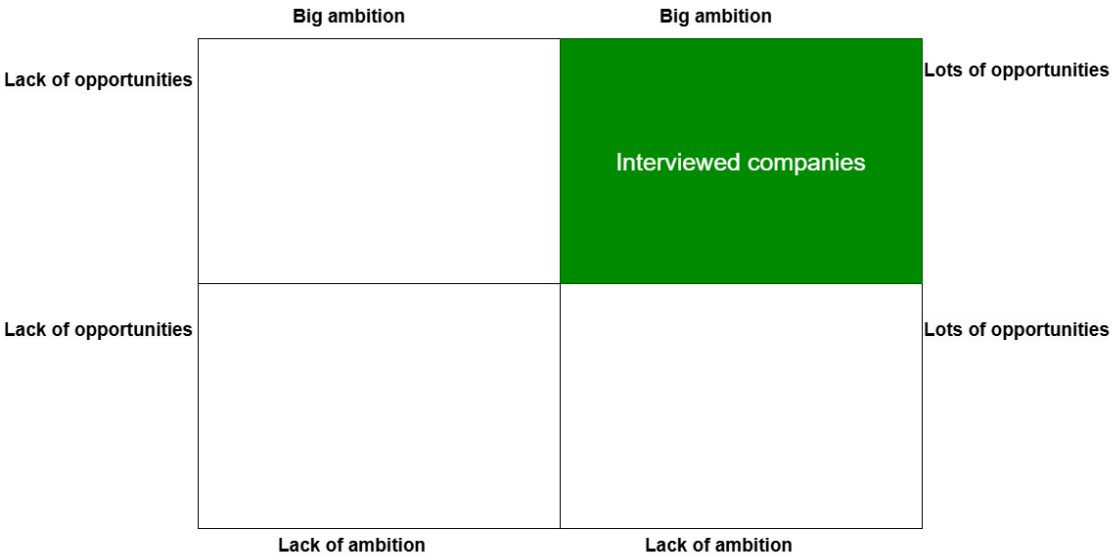

Figure 9. *Twin transition ambitions and opportunities of interviewed companies*

The ambition level of all companies is clear to see. All of the analyzed businesses demonstrate a high level of ambition toward achieving the goals of the twin transition. Companies have a clear understanding on the impact that digitalization can have in reaching the goals of sustainability and there are small differences between the businesses. One company representative explicitly states that they see digitalization as a way of mitigating the effects of climate change and building sustainable solutions for the future. Another business mentions the fact that they want to take concrete steps for improving their services that require digitalization and AI.

Furthermore, there is a shared recognition that improvements in the production asset lifecycle can be achieved through a sustainability-oriented approach. Despite the varied roles that the companies occupy within the production Asset Lifecycle Management ecosystem, a common ambition emerges: to enhance processes and transition toward more circular practices. All organizations acknowledge the significant value of shared data as a driver of these improvements. There are clear ambitions for improving the production processes related to assets by reducing the environmental footprint related to the assets and moving towards more circular processes.

The opportunity level across the interviewed businesses is generally high, with all of them positioned on the positive side of the spectrum in terms of their potential to contribute to and benefit from the twin transition. Various actors within the industrial ecosystem play

different yet complementary roles that collectively enable advancements in digitalization and sustainability.

Technology platform providers offer digital infrastructure solutions, such as digital twins and edge computing, empower industrial customers to enhance production efficiency, optimize resource usage, and integrate advanced technologies like artificial intelligence. Industrial end users, particularly those managing large-scale production environments, stand to gain from improvements in asset utilization, energy efficiency, and lifecycle management, with the potential to scale these benefits across operations.

Service-oriented companies contribute by offering data-driven consultancy and technical support, helping industrial actors implement asset performance improvements and transition toward predictive and prescriptive maintenance models. Equipment manufacturers, on the other hand, focus on improving material and energy efficiency in production processes through data-enabled solutions.

5.3 Insights gathered and moving forward

Overall, it is clear to see that the interviewed companies share a high willingness to join the collaborative production ALM ecosystem that makes sure that production processes improve. The importance of shared data is clear for the companies, and they want to be part of an ecosystem that leverages data for realizing business values and the goals related to sustainability.

The interviews opened up concerns and issues that the companies see disturbing the production ALM ecosystem. From Figure 10, it is possible to see the different elements that need to be achieved in order for the industrial companies to realize the benefits of shared data. Firstly, the data needs to be standardized, which means that it is in consistent format that be exchanged without any issues. To achieve this goal, it is imperative to find the right type of data standards and utilize them. Moreover, when the actual process of data sharing occurs, the data needs to be exchanged using standardized protocols, so the process of exchange is as smooth as possible and happens without any issues. In addition, it is important that companies sharing their data do not have to worry about where it ends up and that clear safety protocols are in place to keep the data safe.

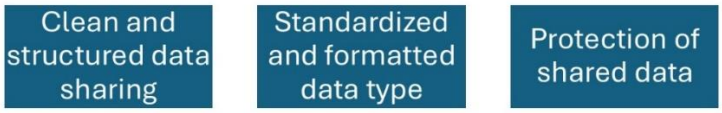

Figure 10. *Requirements related to data*

Figure 10 presents just some of the major requirements related to data that need to be solved in order for collaborative data sharing to take place. Addressing issues like data standardization, data quality requirements, and data security requirements leads to the full value of data being obtained. The following chapter focuses on analyzing an existing data transmission platform, with the focus on seeing how it fulfills these requirements mentioned.

6. BNAC

This section analyzes the collaborative asset management solution, BNAC. Firstly, the solution is analyzed from a general perspective, with a look on how different stakeholders in the production environment benefit from it. Section 6.2 goes through the data taxonomy of the solution. Finally, Section 6.3 looks at how BNAC is able to solve the challenges related to data sharing.

6.1 BNAC platform analysis

Through the collaborative BNAC platform, it is possible to have a centralized asset repository that offers a transparent single source of truth for maintaining asset information in production environments [77]. The solution ensures that there is only one version of the asset, reducing the chances of asset duplication, which leads to inconsistencies and errors. Moreover, through this centralized platform, it is possible to harmonize the collaboration between different stakeholders in the production environment, including OEMs, asset operators and service providers. BNAC provides a straightforward entry point for many external and internal asset stakeholders making the process of handling assets much simpler [77].

BNAC is a software as a service (SaaS) solution. As a SaaS solution, it is hosted on a remote server and can be accessed anytime, anywhere through a web browser [78]. The solution utilizes different data centers based on the region which it is used, including Amazon Web Services, Microsoft Azure, Alibaba Cloud and Google Cloud Platform [79]. As a cloud-based solution, BNAC provides a flexible, modular and centralized platform for different stakeholders. The cloud platform also provides a secure environment for storing and accessing data, with access controls that make sure that only authorized users can access the relevant information [77].

The platform is based on having a shared digital twin of assets that can be accessed by different stakeholders in the project. When a manufacturer provides an asset operator with a physical asset, the operator also receives its digital replica. Digital twins on BNAC act as virtual representations of a physical asses and allow stakeholders to access accurate, real-time data related to industrial assets, like a pump [77]. A digital twin shows a live digital representation throughout the lifecycle of an asset. Through these digital

twins, it is possible to continuously improve asset performance, conduct predictive maintenance tasks and have the knowledge of remaining lifetime of assets [80].

The technologies of BNAC simplify asset management by providing a single location for managing all assets and by bringing together different stakeholders throughout the asset lifecycle [81]. A centralized asset repository enables collaboration between stakeholders, resulting in enhanced communication and sharing of asset data breaking the organizational siloes that exist [77]. Moreover, the platform makes sure that there is only one version of the asset that every party utilizes, which makes sure that there are not any different versions of the assets leading to inconsistencies and data redundancy [81]. In addition, BNAC provides a platform that with a high degree of data integrity and consistent data taxonomy, which ensures a high quality of asset master data that is utilized by everyone on the network [77]. Figure 11 displays a comprehensive depiction on what BNAC aims to achieve.

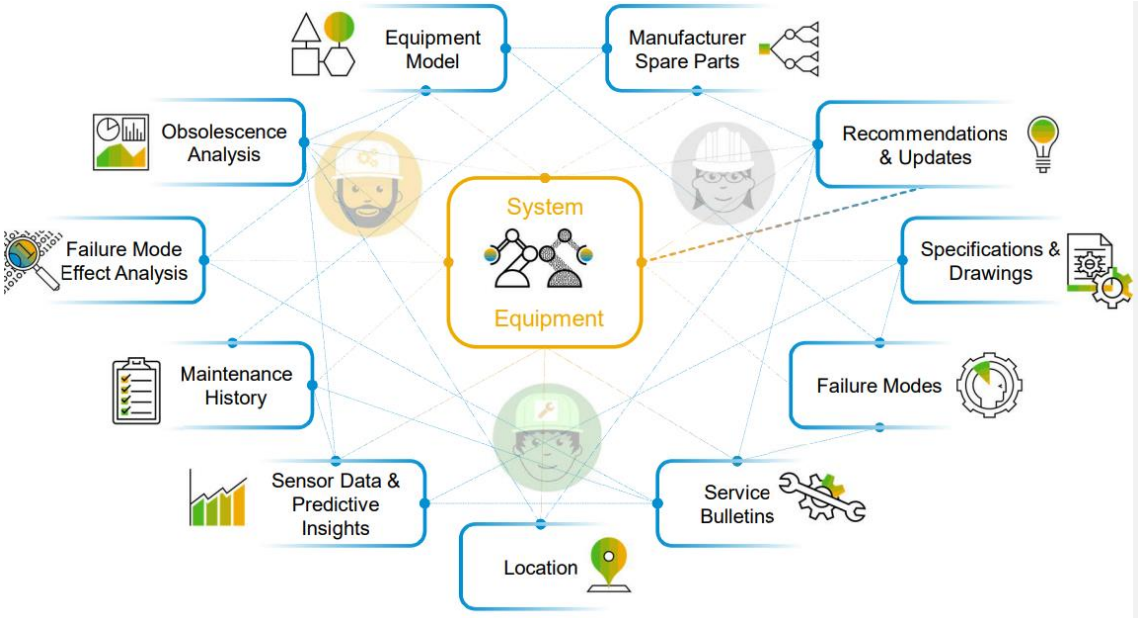

Figure 11. *Collaborative asset information* ***[81]***

Through BNAC, asset operators can directly interact with OEMs, facilitating a direct channel for both receiving information from OEMs and sending information to them. This enables OEMs to create improvements in areas like design, installation and performance of an asset [77]. Moreover, the platform allows manufacturers to create innovative business models like offering equipment as a service. These improvements from the OEM side result in better offerings for asset operators. Moreover, BNAC provides a pathway for collaborative maintenance between the asset operator and the different service providers they interact with. Through the platform, the asset operator can directly interact

with several service providers and have a direct relationship with them. This will give service providers immediate access to crucial data like asset health scorers and remaining lifetime information enabling the anticipation of potential failures and the replacement of assets in a timely manner [77] . By decreasing the asset downtimes, lost time in production is minimized, leading to decreased revenue losses and reducing wastes generated from asset usage [77].

6.2 Data taxonomy in BNAC

Figure 12 presents the data objects that are present in BNAC. Firstly, there are templates, which are predefined structures utilized to standardize information exchange [82]. Templates are utilized to maintain metadata-related information linked to the production process, with each template identified uniquely named and made up of attribute groups and individual attributes. An attribute group is utilized to logically group a set of attributes together. A certain attribute can be assigned to multiple attribute groups. An attribute is an independent property that forms a structure defining the characteristics of the property. These characteristics include ID, attribute description, and the data type; for example, Boolean, date, and string [82].

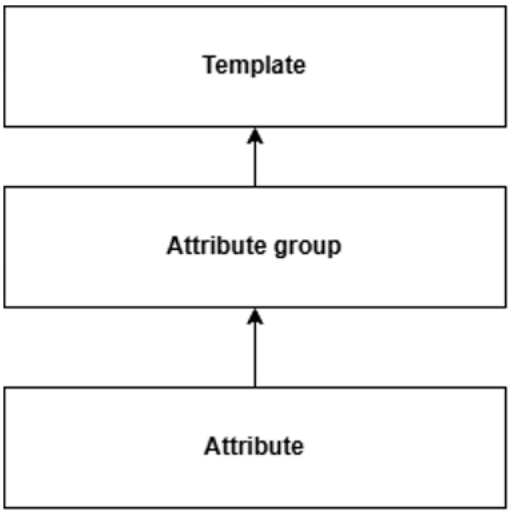

Figure 12. *Data object of BNAC*

Classes are templates provided directly by the BNAC platform, and they are based on industry standards. Through these industry-based classifications, it is possible to maintain asset data integrity and asset maintenance behavior [83]. The classification structure, as well attributes assigned and attribute groups, are based on certain standards. Classes are the highest level of classification provided in BNAC. Moreover, subclasses

are child objects of a class, inheriting attributes from their parent objects [82] One of standards supported is the International Organization for Standardization (ISO) 14224, which is dedicated to the collection and exchange of reliability and maintenance data in the petroleum, petrochemical, and natural gas sectors [83]. The standard provides data requirements for the type of data to be collected and standardized data format to facilitate data exchange between stakeholders [82].

Models are abstract representations provided by the manufacturer that describe all the maintenance and specification data linked to an asset. The asset operator can then define equipment as an instance of the model [82] . Figure 13 illustrates the relationship between a model and equipment. A certain model can be used to create multiple distinct pieces of equipment. Each model needs to be created only once, and then it can be shared to asset operators in different companies making the whole process extremely straightforward and standardized

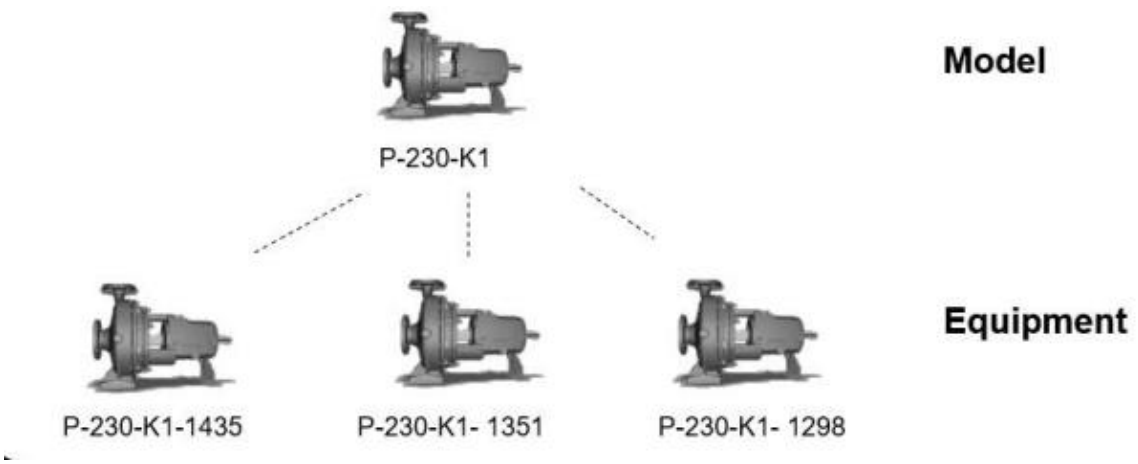

Figure 13. *Relationship between model and equipment* ***[84]***

6.3 Solution overview from data sharing perspective

In Section 5.3, some of the major requirements raised by the interviewed businesses for joining a collaborative data sharing ecosystem were presented. These requirements, along with the impact that BNAC has on addressing them, are now summarized in Table 3. The table illustrates how BNAC is able to solve some of the key problems identified in the interviews.

Table 3. *BNAC impact based on data sharing requirements*

Requirement	**BNAC impact**
Protection of shared data	Only authorized users have access to data
Clean and structured data sharing	Centralized platform that makes data exchange seamless
Standardized and formatted data type	Clear data taxonomy and models defined

Firstly, a big requirement was that there was a need for data standardization, with the data coming from various sources and being of different type. As illustrated in Section 6.2, BNAC offers clear data taxonomy and standardization related to asset data. The solution ensures interoperability by following industry standards like ISO 14224. Moreover, the solution reduces duplication through reusable models and classifications. Finally, the solution maintains asset data integrity by enforcing clear taxonomy and classification hierarchy.

Another need from businesses was to obtain a way that makes data sharing clean and structured. BNAC provides a common platform that allows all the different stakeholders in the ecosystem to share production-related data seamlessly. The platform can be accessed remotely by all the stakeholders, providing a centralized location for managing all data. It is also possible to share data to the platform through REST-based API's, offering another effortless avenue for sharing data.

One of the big issues with data sharing mentioned by the companies was the fear related to data security, and data ending up in the wrong hands. In addition, companies expressed a need for better control of data sharing including ownership and traceability. BNAC offers a secure cloud environment for managing data. By storing assets in a centralized repository, businesses can better control who has access to data. Moreover, the platform provides granular access controls, meaning that only authorized personnel get access to the relevant information.

7. DISCUSSION

This chapter analyzes the findings of the research in depth. Firstly, Section 7.1 analyzes the biggest insights from the theory and interviews, and presents a PESTEL analysis is based on them. Section 7.2 looks at the viability of BNAC solution for the target organization. Lastly, Section 7.3 presents a preliminary roadmap on how the solution could be implemented within the target organization.

7.1 Collaborative data sharing ecosystem requirements

Firstly, the research found many motivation factors for companies to join the ALM ecosystem. One of the biggest factors mentioned in the interviews was the goal of moving towards a sustainable society. There is a clear belief that through digital transition the industrial processes can be optimized and operated more sustainably. These insights corroborate with the findings from the literature review, which showed that digital transition has a positive effect on sustainability and the transition towards a greener feature. The literature review also reiterated the positive benefits that inter-organizational data sharing presents for sustainability.

The interviews also revealed different challenges that businesses face in the collaborative asset lifecycle business. There are many factors related to data that bother the interviewed companies. The biggest bottleneck for sharing data was found to be the hesitancy for sharing data, as data is seen an as a key offering for many businesses. Losing this kind of business value causes concerns about data sharing. This point aligns with the study of Eger and Scheufen [45], who emphasize the fact that companies are wary of providing unrestricted access to other parties. In addition, interviewed companies worried about the fact that once the data is shared, there is no control of what happens with the information. Another point raised was the insufficiencies in data quality and standardization, which makes the data sharing process difficult. The paper by Jussen et al. [43] supports these findings and emphasizes that without the sufficient quality of data, the value obtained from it is minimal.

Based on the theory chapter and the interviews conducted, the current landscape related to data sharing from the twin transition context has become clear. Now, the PESTEL tool will be utilized to present the different aspects that need to be addressed, so that businesses are able to join a collaborative data sharing ecosystem. The analysis is based on

both the literature and the interviews conducted, in order to create a general framework for creating a data sharing ecosystem. Each aspect of the PESTEL will be analyzed from two perspectives: big picture aspects that are generally linked to twin transition, and specific factors that are linked to data sharing. Figure 14 presents the PESTEL analysis that has been created.

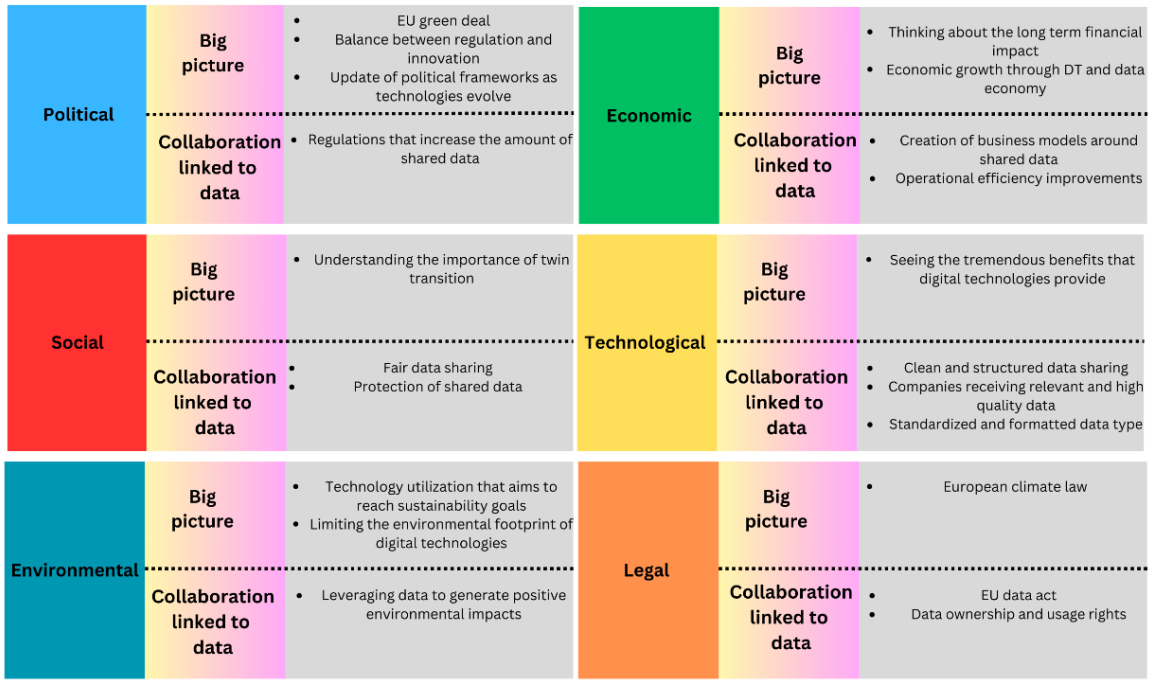

Figure 14. *PESTEL analysis*

Firstly, as a business operating in the EU, there are many EU policies that come into effect. The European Green Deal is a policy that strongly facilitates the twin transition of businesses. EU's new industrial strategy aims to reduce CO2 emissions by providing clean technology solutions that are affordable, and creating new business model [85]. However, as discussed earlier in the theory section, the amount of regulation in the digital sector in the EU is strong, which can hinder digital innovation and evolution. For twin transition to occur, it is crucial to find the right balance of regulation. In addition, political frameworks need to be updated as the digital technologies evolve to fully obtain the benefits from these technologies. Moreover, to enable data sharing between companies, it is important that there are regulations that aim to make data sharing easier and this is what European strategy for data is aiming to achieve.

Both the theory and the interviews concur to the fact there might be short term financial losses when aiming to move a business towards achieving the goals of green transition, but that the long-term economic benefits are clearly worth it. This is why businesses need to be prepared for the initial costs that are linked with digital transition. Moreover, research shows that digital transition and data economy offer huge potential for companies to acquire economic growth. As seen from the previous sections, the potential for creating novel business models from shared data is huge, and this is something that companies want to be part of.

It is crucial that the importance of twin transition is understood by people in key positions within businesses, which leads to a cultural shift inside organizations in terms of understanding the importance of the transition and actively taking steps to achieve it. In terms of data sharing between businesses, it is important that data is shared in a way that is transparent and responsible. This requires the implementation of clear mechanisms to protect shared data and ensure that shared data does not end up in the wrong hands, as this remains a huge concern for businesses. It is vital that these concerns related to data sharing are taken care of to make businesses more open of joining a data sharing ecosystem.

This thesis has clearly demonstrated the huge impact that digital technologies can have towards moving a green future and also acquiring economic benefits. In the context of interorganizational data sharing, certain technological requirements must be met for achieving the twin transition goals. Firstly, the data needs to be standardized, meaning that it is in a consistent format that can be exchanged without issues. To achieve this goal, it is imperative to find the right type of data standards and utilize them. Moreover, when the actual process of data sharing occurs, the data needs to be exchanged using standardized protocols, so the process of exchange is as smooth as possible and happens without any issues. In addition, it is crucial to make sure that the data exchanged is relevant and presents value for the receiving company. This can be achieved by having certain standards that the data can be compared to.

From the environmental perspective, the twin transition goals are achieved when technologies are utilized in a way that supports broader sustainability related goals, as highlighted throughout the thesis. Digital technologies offer a strong path of achieving the goals related to sustainability. However, it is also important to keep in mind that that digitalization can contribute to greenhouse gas emissions if not properly managed. Therefore, it is crucial to align digital transition strategies with green transition principles to minimize their environmental impact. In addition, it is important that shared data is

utilized in a way that enhance the sustainability of business processes. For example, utilizing data to optimize resource usage and using resources in a circular way.

In the EU, the European green deal includes a law called the European Climate Law. This law sets the goal of EU being climate-neutral by 2050 by cutting emissions, investing in green technologies and protecting the natural environment [3]. In terms of data sharing, the EU data act wants to make data, especially industrial data, more accessible and usable. This makes sure that businesses will be able to access data that was previously restricted or behind a paywall. [44] However, businesses also needs some legal assurances that data ownership and usage rights are made clear so it is clear that which parties can access the data. All of these political factors will lead businesses achieving the goals related to twin transition.

7.2 BNAC analysis

From the interviews, it was seen that the companies want to find digital tools that enable seamless data sharing in an interorganizational way. This paper, especially focused on finding a solution for Metsä Group, a Finnish forest company that utilizes tremendous amount of physical assets in the production environment. It is important to note that Metsä work with many different businesses in the production environment, meaning that, by design, the impact of the solution will extend to these partner companies as well.

SAP offers a wide range of digital enterprise solutions that can be utilized for business process improvements. They are known for their ERP solutions, which are also utilized across Metsä Group's business processes. As SAP's solutions were already integrated heavily into the company's processes, it seemed suitable to find out whether SAP's Business Network Asset Collaboration tool would be the right fit for collaborative asset management that lead to sustainable development and production efficiency benefits.

This thesis went through the general features of SAP's BNAC platform to find out whether this solution could enable collaborative asset management between stakeholders and present concrete benefits from the perspective of sustainable development and production efficiency. In Section 6.3, some of the major challenges related to data and data sharing that bothered the interviewed businesses were shared. It was seen that many of the requirements set out by the interviewed businesses were accomplished by BNAC.

Table 4 presents a comparison of some of the key parts of previous section's PESTEL analysis and how the features of BNAC compare to the PESTEL. This comparison is

created to provide an more holistic overview of BNAC by analyzing it across multiple different dimensions.

Table 4. *BNAC impact to the PESTEL requirements*

Dimension	**Sub-element**	**BNAC impact**
Economic	Operational efficiency improvements	Better asset usage, reduced downtime
	Creation of business models around shared data	As-a-service business models
Social	Protection of shared data	Only authorized users have access to data
Technological	Capitalizing on the of benefits digital technologies	Cloud computing and digital twin play a major role
	Clean and structured data sharing	Centralized platform that makes data exchange seamless
	Standardized and formatted data type	Clear data taxonomy and models defined
Environmental	Leveraging data to generate positive environmental impact	Enables energy-efficient utilization of assets and circular asset usage

From the economic perspective, there are benefits that can be achieved with BNAC. Through continuous data related to assets and their performance, improvements related to assets and their usage can be maximized leading to maximized performance of assets for asset operators such as Metsä. In addition, through collaborative maintenance with service providers, supported by relevant data, improves predictive maintenance and reduces production downtimes. These are just some of the features of BNAC that lead to operational efficiency improvements and provide the asset operators with continuous benefits throughout the lifecycle. In addition, BNAC can be utilized for creating novel business models for many stakeholders based on shared data. For example, manufacturers can offer digital services like equipment-as-a-service. By offering the chance to create new business models, more actors will find joining the ecosystem advantageous.

From the social perspective, BNAC enables a safe platform where the data can only be accessed by the entities that the data sharer wants. This was one of the key aspects that had hindered businesses of sharing data mentioned both in the literature and the interviews. By having a clear safety protocols in place, makes businesses' more comfortable in joining the ecosystem and makes brining novel partners to the system easier.

The PESTEL analysis highlighted importance of capitalizing on the benefits of digital technologies, and this is exactly what BNAC achieves by leveraging two key technologies that enable digital transition: cloud technology and digital twins. By integrating BNAC into their operations, businesses enhance the digitalization of their processes and acquire the benefits that it provides. Moreover, the literature review and interviews came up with a lot technological factors related to data that bother businesses and inhibit collaboration linked to data. BNAC makes the actual process of sharing data between stakeholders structured and seamless. Moreover, all of the stakeholders utilize the same data models and standards, resolving data interoperability and heterogeneity issues.

This thesis has extensively focused on looking at how digitalization can enable green transition, especially focusing on how this can be achieved by sharing data in the production environment. The data sharing between production environment stakeholders results in optimal usage of assets, which creates benefits like energy-efficient production processes. Moreover, the predictive maintenance features avoid greater damage to machine parts, leading to lifetime extensions of these parts, saving resources, and supporting the principles of circular economy.

Overall, it is evident that BNAC provides a collaborative data-sharing platform that enables different stakeholders to collaborate over the production process. For the target organization of the thesis, Metsä Group, BNAC presents a pathway for enhancing production efficiency of their mills along with achieving the broader sustainability goals set by the company. For Metsä, the features are not the only good thing about BNAC. Since the company already relies on SAP for its overall ERP system, integrating of BNAC with the broader ERP solution becomes seamless. This eliminates the need for complex workarounds and ensures that the data from BNAC can flow directly into the broader EPR system enhancing visibility, data consistency, and automation across core business processes, making the processes even more streamlined.

7.3 Solution roadmap

As BNAC has been identified as a suitable solution for the target company, a structured approach is required to ensure its effective implementation. Given the complexity of Metsä Group’s production processes and the collaborative nature of BNAC, a phased implementation strategy provides a clear pathway for integrating the platform while minimizing operational disruptions. A roadmap serves as a practical guide to ensure that the

transition is well-planned, technically sound, and aligned with Metsä's broader strategic objectives.

By outlining key phases, ranging from technical planning and testing to full-scale deployment and continuous optimization, the roadmap ensures that each step of the implementation process is systematically managed. This structured approach allows Metsä to gradually integrate BNAC into its operations, ensuring that all stakeholders are aligned and that potential challenges can be addressed proactively. Additionally, a well-defined roadmap facilitates smoother onboarding of external partners, allowing Metsä to fully capitalize on BNAC's ecosystem-driven benefits. This roadmap can be seen as an initial plan that helps the company to plan the solution implementation.

A roadmap is created and is presented in Figure 15. The roadmap includes the steps for the next three years: 2025, 2026, and 2027. In addition, it includes the year 2030 to look at the long-term horizon of what can be achieved with the solution. The steps in the roadmap are looked at from a quarterly perspective.

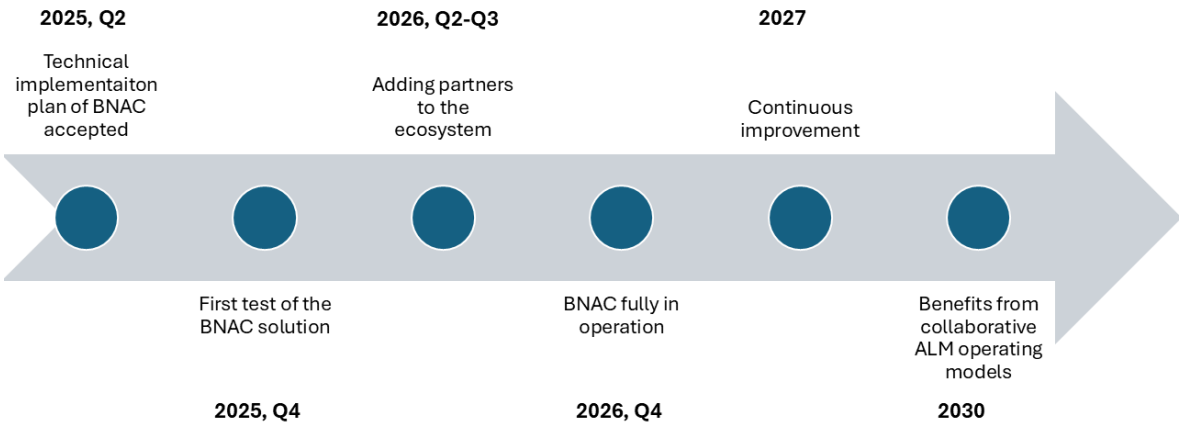

Figure 15. *BNAC roadmap for Metsä Group*

During Q2 of 2025, the aim will be to have an technical implementation plan that shows how SAP's BNAC platform will be integrated into Metsä Group's production processes. This will be done in collaboration with SAP personnel, who will provide valuable information regarding what the actual implementation requires and how to best proceed with

the process. As Metsä's operations consist of numerous production processes, it is imperative that the implementation plan accepted is holistic and general enough to a clear framework on how to implement the solution. During this phase, the implementation plan will be approved internally by the relevant decision-makers within the organization. The next step is to begin the actual design phase. The design phase will look at how the testing of the BNAC platform will be conducted. It is important to establish clear objectives for the actual testing process, for example, validating the data-sharing capabilities of BNAC, and the solution's integration with existing solutions. Finally in Q4, the first test of the BNAC solution will occur within an upcoming project of Metsä Group, with the details related to the project being revealed at a later stage.

The aim is that during the year 2026, different partners of Metsä Group in the production asset lifecycle will be added to the BNAC ecosystem. This includes partners within different roles, such as manufacturers or maintenance service providers, who will begin utilizing the platform, thereby extending the data-sharing ecosystem. By the end of 2026, BNAC should be integrated fully into Metsä's processes. This means that the production processes are fully integrated with the platform, and the partners of Metsä are part of the ecosystem.

During 2027, the focus will be on achieving continuous improvement in Metsä Group's production processes. As the BNAC utilization will still be in the early stages, it is imperative that there will be iterations occurring related to the solution usage. At this stage, it will be crucial to find out whether the platform is bringing the kind of production efficiency benefits that were anticipated initially.

By 2030, the aim is for Metsä to have a collaborative asset lifecycle management models in place that are able to make the production processes of the company more efficient and sustainable. The ideal situation would be that BNAC will be utilized across Metsä's processes with all the partners of Metsä participating on the platform. These potential enhancements on the production processes will present a pathway of achieving wider strategic sustainability 2030 goals of Metsä Group, with one of the targets being 10 units' improvement in energy efficiency in Metsä's processes compared to 2018 [86]. Moreover, the company is eager to reach the different targets set by EU for 2030, including the 2030 climate targets and energy efficiency targets.

8. CONCLUSION

This chapter evaluates how the objectives of the research have been achieved and reveals the implications of the findings. Firstly, the research questions of the study are explicitly answered. Following that, the study implications are presented. Finally, the limitations of the study are presented.

8.1 Answering research questions

What influences a company's decision to take part in a data-sharing ecosystem within the collaborative asset lifecycle business?

Businesses demonstrate clear motivation factors for joining a data sharing ecosystem. Very importantly, all the interviewed companies recognize the importance of twin transition and the role of digitalization in enhancing sustainability targets. The businesses recognize the sustainability benefits a data-sharing ecosystem provides and are eager to move towards this. Another motivating factor for businesses are the business opportunities that shared data provides. For example, asset operators see that they can utilize their assets better throughout the production, while service providers see that they can offer data-driven services.

In terms of challenges, the interviewed companies mentioned quite a few of them. Interviewed companies indicate that there is a general hesitancy among companies to share data within the industrial lifecycle ecosystem. The biggest issue comes from the fact that many businesses derive significant business value based on their own data and are reluctant to share this information with other businesses to capitalize on. Another major hurdle are the technical challenges, like insufficient data quality and standardization, and lack of data transmission avenues.

All in all, the answers to the first research question was answered quite extensively based on the interviews conducted. The interviews gave a holistic overview of different aspects related to the businesses in production asset ecosystem and helped with the understanding of the aspects that motivates them to join the ecosystem and also the aspects that hinder them joining. These insights alongside the literature review conducted previously, provided a thorough understanding of the different factors that need to be happen, in order for collaborative asset management to take place.

What are the technologies that can be used to enhance data sharing in collaborative asset lifecycle solutions?

The impact of digital transition was established clearly in the theory section and through the interviews. By going through specific digital technologies, it became clear what kind of different features each technology offers and how businesses could utilize them in their own production processes. Based on the research, it can be clearly stated that digital technologies offer several benefits in improving collaborative asset management in the production environment.

Through the utilization of Artificial Intelligence in ALM, asset usage can be optimized. AI enables analytics and pattern recognitions that help anticipate failures before they occur, reducing maintenance costs and downtime. Moreover, cloud computing is an another key technology that offers strong benefits in asset management. A cloud-based asset management system enables real-time access to asset data from any location, and it provides centralized access to multiple different stakeholders in the production environment. Digital twins provide a live representation of the asset throughout the lifecycle, leading to continuous improvements in asset performance. Another key part of digital twins is their ability to predict asset performance leading to improved predictive maintenance. For digital twins to work optimally, there is a need for large amounts of data and this is where the importance of IoT comes in. IoT devices allow the tracking of key data related to the assets, which can be utilized by digital twins. Finally, edge computing enables even quicker data processing that makes data distribution even faster between stakeholders.

How to concretize the benefits of shared asset data from sustainable development and production efficiency perspective?

The aim of this research question was to find a digital solution for the target company, Metsä Group, for sharing data between its different stakeholders in the production lifecycle. The solution chosen was SAP's Business Network Asset Collaboration (BNAC).

BNAC provides a centralized repository for accessing asset-related data from all the different stakeholders in the ecosystem. This ensures that all participants have access to the same data, leading to data consistency and reducing data redundancy. In addition,

BNAC utilizes standardized data models and data taxonomy for all stakeholders. Together, these features result in higher data quality, enabling faster and more informed decision-making in the production environment.

High-quality and consistent master data leads to improved decision-making throughout the lifecycle of assets. This streamlines processes and reduces the errors that are made throughout processes. Moreover, BNAC increases operational reliability through predictive maintenance and real-time condition monitoring. By combining data with different digital technologies such as AI, enables businesses to detect issues early and prevent sudden failures in the manufacturing processes. Finally, BNAC leads to enhanced responsiveness of the production environment with real-time data sharing enabling quicker response times when services and repairs are required.

BNAC also plays a crucial role in improving sustainability by optimizing asset management and reducing environmental impact. Predictive maintenance minimizes unnecessary part replacements, leading to less material waste and a longer asset lifespan. This not only reduces resource consumption but also lowers the environmental footprint of production operations. Additionally, optimized asset performance through real-time data utilization makes sure that assets operate at peak efficiency, reducing excess energy consumption. Furthermore, at the end of an asset's lifecycle, BNAC supports that the effective assessment of components and materials for reuse, refurbishment, or recycling. This approach reduces waste and promotes the circular utilization of parts. By maintaining detailed lifecycle related data, BNAC enables to determine which parts can be remanufactured or repurposed instead of being discarded.

The aim of this research question was to identify an already existing digital tool that enables collaborative asset management while supporting both sustainability and production efficiency improvements. SAP's BNAC platform demonstrates a solution that fits these parameters, and thus will gives Metsä Group a solution that enables improvements in their production processes. The next steps would be for the business to start preparing for the solution implementation.

8.2 Implications

The findings of this research provide valuable insights into the role of data sharing in facilitating the twin transition—the simultaneous pursuit of digitalization and sustainability in in the production processes in the forest industry. For businesses, this research highlights that data sharing is not just a technological advancement but a strategic necessity

in the transition toward more digital and sustainable operations. Companies that embrace collaborative data ecosystems can enhance operational efficiency, optimize resource use, and drive innovation. By integrating data-sharing solutions into their processes, firms can improve predictive maintenance, reduce downtime, and minimize waste, leading to both economic and environmental benefits.

However, companies must address key challenges such as data security, interoperability, and trust. Establishing standardized data formats and ensuring transparency in data-sharing agreements will be crucial for fostering collaboration across industries. Organizations that successfully navigate these challenges will gain a competitive advantage, as they will be better equipped to comply with evolving sustainability regulations while also leveraging digital transformation to optimize their business models.

The research found an existing digital solution that enables collaborative data sharing and would enable the case company of this thesis to acquire the benefits of shared data. This solution solved many of the problems that generally bother businesses related to data sharing enabling a collaborative ecosystem that the company can utilize for sharing data between its stakeholders in the production process. For the case company, the next step would be to integrate aforementioned or a similar kind of solution into their business operations.

8.3 Limitations

One of the limitations of this study is that the interviews conducted in the first part of the research were part of a larger research project, in which the author of this thesis participated. While the author's involvement allowed for firsthand engagement in the data collection process, the structure and focus of the interviews were influenced by the broader objectives of the larger research project. As a result, certain aspects specifically relevant to this thesis may not have been explored as thoroughly as they might have been if the interviews were fully designed by the author.

Another limitations of this study is that the analysis of SAP BNAC's data transmission platform was conducted at a general level, relying on material retrieved from online sources, including SAP's official website and other resources that have discussed or implemented the BNAC solution. As a result, the study lacks detailed empirical insights from real-world implementations.

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